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1 April 1987

INDUSTRIAL TECHNOLOGY MODERNIZATION

Phase II Final Report
Project 12
Mechanical Inspection Cell

INDUSTRIAL
TECHNOLOGY MODERNIZATION
PROGRAM

Prepared for
GENERAL DYNAMICS
Fort Worth, Texas

Contract No. F33657-82-C-2034

Delco
Systems
Operations

DELCO ELECTRONICS CORPORATION
Goleta, California 93117

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This is a semiautomatic vision system to inspect part dimensions, combined with robotic gauging of threaded holes. The project is complete but never implemented due to a lack of F-16 business. → & page 1

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Delco Systems Operations

DELCO ELECTRONICS CORPORATION
Goleta, California 93117

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ILLUSTRATIONS

1.0 INTRODUCTION

This report~~, the Project 12 Final Report,~~ presents program efforts ~~during the period May 1, 1984 through January 31,~~ 1987 in support of Phase II of the Industrial Technology Modernization (ITM) program sponsored by General Dynamics, under contract No. F33657-82-C-2034. Phase II is dedicated to demonstration of enabling technologies for the factory modernization projects.

1.1 BACKGROUND

A Phase I Technology modernization program was performed at Delco from October 1982 through September 1983. Objectives were to conduct an analysis of manufacturing processes and facilities to be used in the production of DOD deliverable hardware, and to evaluate and identify new technology modernization projects that could, if implemented, significantly reduce deliverable unit costs. Both direct (i.e, Manufacturing Operations) activities and indirect (i.e., Manufacturing Management) activities were considered.

fr p. 1

2.0 OBJECTIVE

As a result of the Phase I efforts conducted under the Tech Mod Program, Delco proposed to General Dynamics a continuation of the Manufacturing Modernization Program, under Phase II, A Mechanical Inspection Cell (Project 12). This project deals with the design of a work cell to automatically inspect mechanical components as a receiving inspection operation. Specific functions of this work cell were dimensional inspection, thread gaging, and material handling. (SOW)

3.0 A COMPARISON OF PRESENT AND PROPOSED METHODS

3.1 PRESENT

The present method of inspecting mechanical components is to manually verify each dimension using vernier calipers. Those dimensions that can not be checked with vernier calipers are checked using the appropriate gaging, such as threads/thread gage, radiuses/radius gage, center-to-centers distances of holes/coordinated measuring machine, and depths/depth micrometers.

The parts examined are primarily cast or machined aluminum and range in size from 0.375 inches to 22 inches. The parts are primarily used in military products and require thorough inspection. See Figure 1 for typical mechanical parts. A preselected quantity of parts from a manufacturing lot are subjected to first article examinations. These first article parts are 100% inspected for part-to-drawing conformance. The remainder of the parts from the manufacturing lot are checked for predetermined dimensions, specifically those dimensions critical to the function or assembly of the parts or those dimensions frequently not held during the machining operations. An inspection record is maintained for each part to permit quality trend reporting.

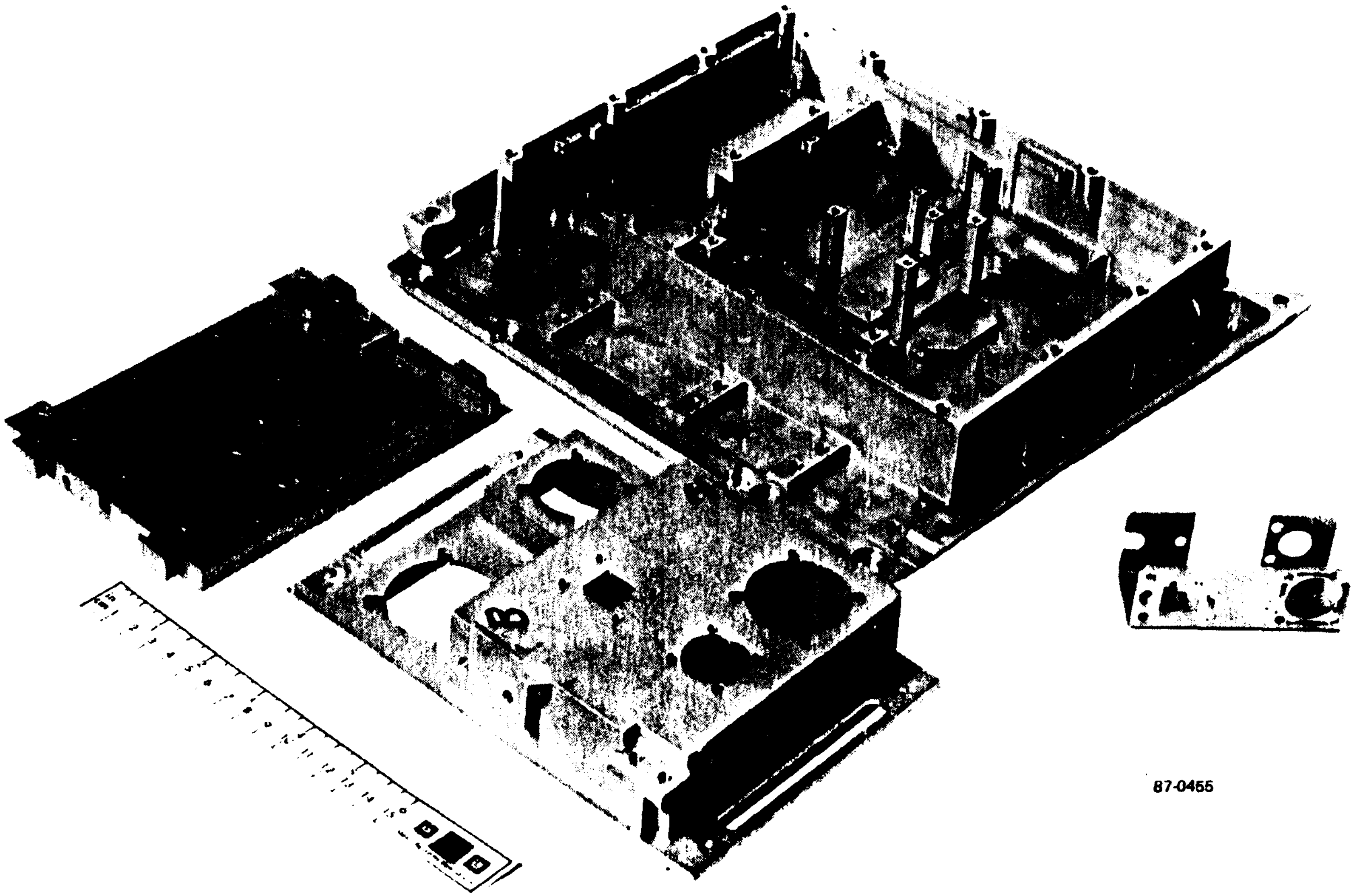
3.2 PROPOSED

3.2.1

The proposed method of dimensional inspection is to use a semi-automatic vision sysstem whereby all part dimensions would be checked using vision system principles. This method utilizes an X-Y servo-motor-driven table with a camera mounted in the Z-axis. Since the X and Y dimensions are in the same plane, the planar dimension is established by the distance the table travels plus the camera's interpretation of the edge of the surface feature being inspected. A built-in algorithm establishes the planar dimension that has been checked. The dimension along the Z-axis is a function of the focal length of the camera. One plane is established as the zero or reference point, with the depth being a new plane requiring a new focal length. The distance the fixed focal length camera moves along a Z axis determines the Z dimension of the part feature being examined.

3.2.2 The proposed method of thread inspection will use a robotic system equipped with an end effector capable of driving a Go or No-Go gage into a tapped hole while monitoring torque. When a predetermined torque threshold, based on thread size, is attained the system will discontinue driving the gage into the part. During gage extraction revolutions will be counted allowing the depth of the threaded hole to be determined. The end effector would also contain a tool changer to accomodate differences between Go and No-Go gages.

TYPICAL MECHANICAL PARTS



87-0455

Figure 1

3.2.3 To maximize the Workcell's throughput a material handling system would also be utilized. This system would be comprised of a robot and the necessary quick change end-effectors to handle the variety of parts the workcell would see.

4.0 PROPOSED TECHNICAL APPROACH

Based on an initial mechanical inspection cell definition, expected results from such a system, and information gathered on existing inspection equipment identified during Phase I of the ITM Program, the following scenario was generated to further define a final system's approach and design criteria. A concept layout of the inspection cell and system breakdown are shown in Figures 2 and 3.

4.1 INSPECTION CELL DEFINITION

The inspection cell shall consist of: 1) 3-dimensional vision system station to be used for measuring features of a part; 2) a robot station that would utilize modified go/no-go thread gages to inspect tapped holes; 3) a system supervisory computer to control, transfer, and store data; 4) a material handling robot system to automatically load and unload each station as required; and 5) a safety system.

The inspection cell shall have a working envelope (X,Y, Z) of 18 x 24 x 6 inches and a maximum inspected part weight of 12 lbs.

Part fixturing requirements will want to be semi-dedicated, allowing for common usage between several classes of parts to be inspected. All fixturing will also be manually loaded and unloaded.

4.1.1 DIMENSIONAL MEASUREMENT STATION

The 3-dimensional vision system chosen is a View Engineering Model 1200. It consists of: 1) A System Control Unit (SCU), 2) A Data Gathering Unit (DGU), and 3) part position monitor.

4.1.1.1 The SCU handles overall control of the vision measurement system. It includes a TV monitor, keyboard, two floppy disk drives (638K each), one 10-megabyte hard disk, and an 8086/8087 16 bit CPU. Data is downloaded to it from the primary computer and supplied software along with built-in algorithms instruct the DGU to perform all required inspections.

4.1.1.2 The DGU accomplishes the actual data measurement. It utilizes a high resolution video camera system mounted in the Z-Axis and an X-Y servo-motor-driven table onto which the part to be inspected is mounted. Since the X and Y dimensions are in the same plane, the planar dimension is established by the distance the table travels plus the camera's interpretation of the edge of the surface feature being inspected. A built-in algorithm establishes the planar dimension that has been checked. The dimension along the Z-axis is a function of the focal length of the camera. One plane is established as the zero or reference point, with the

ITM PROJECT 12 MECHANICAL INSPECTION CELL

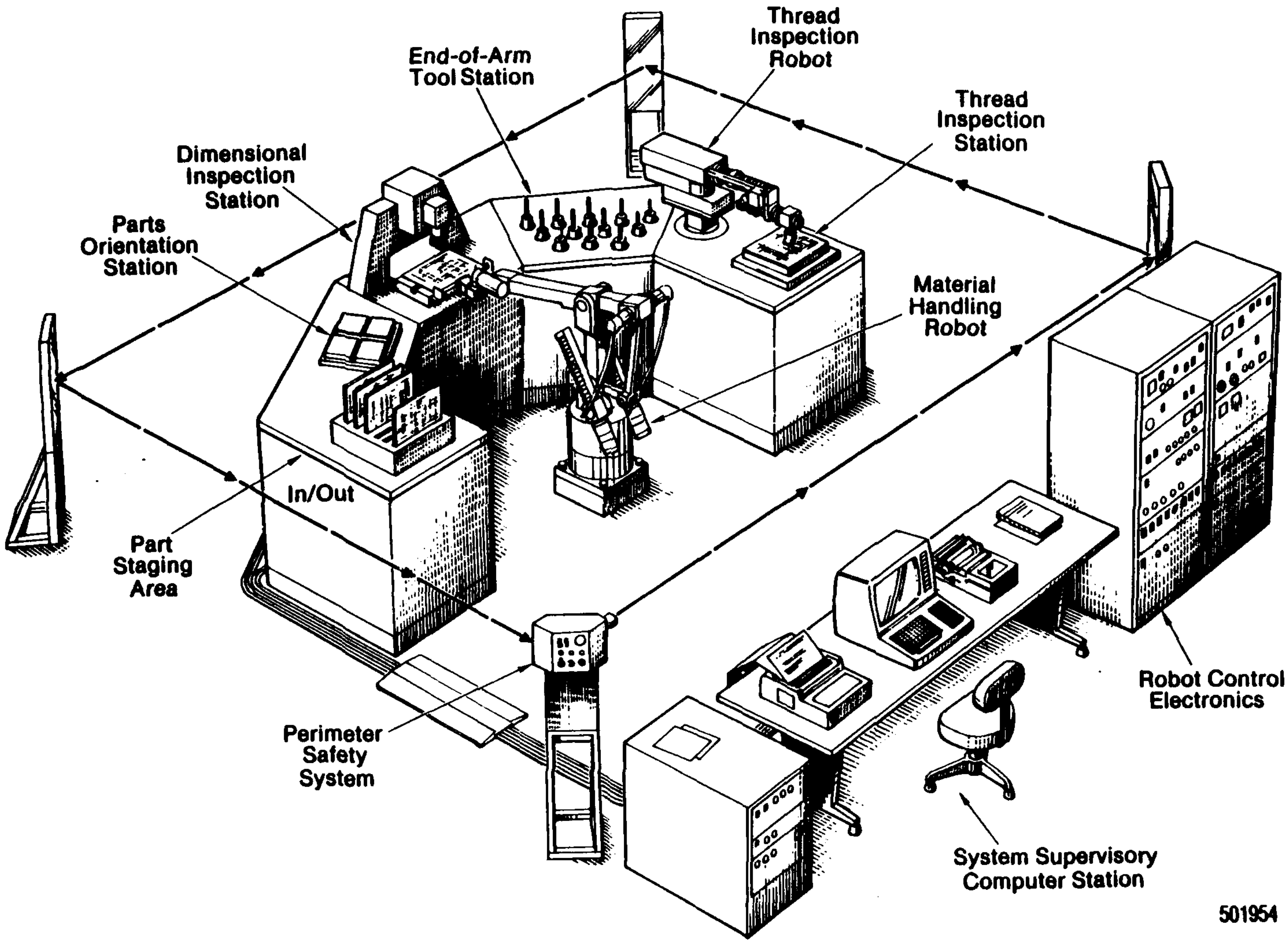


Figure 2

ITM PROJECT 12 - MECHANICAL INSPECTION CELL

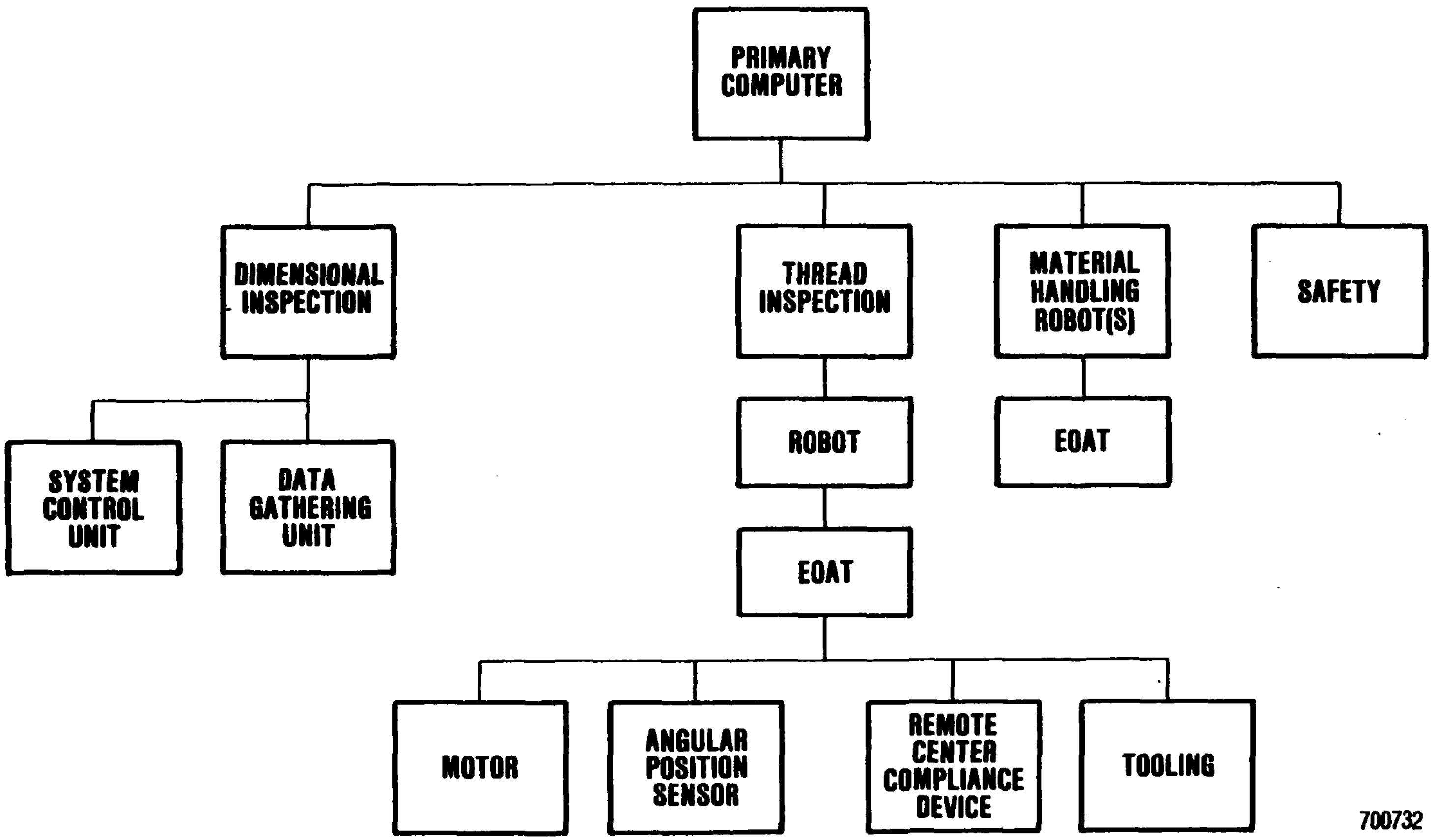


Figure 3

depth being a new plane requiring a new focal length. The distance the fixed focal length camera moves along a Z axis determines the Z dimension of the part feature being examined.

4.1.2 THREADED HOLE INSPECTION

Threaded hole inspection will be accompllished using robotic thread gaging, This system consists of a robot, robot controller, and end effector tooling that will inspect threaded holes (#2 through 1/4 inch) for correct size, class and thread length, per FED-STD-H28/6.

4.1.2.1 End effector tooling (see Figure 4) contains a motorized spindle capable of driving the thread gage, a rotational measurement device (Resolver/Potentiometer), a 6-axis force sensor containing a microprocessor capable of torque monitoring and force feedback to facilitate fine robot positioning, and thread gage tooling capable of automatic tool changing.

4.1.2.2 Alignment of the end effector tooling to the tapped hole shall be adequate enough to guarantee that 95% of any torque monitored will represent true torque values and not be due to side loading.

4.1.3 SYSTEM SUPERVISORY COMPUTER (SSC)

The SSC handles overall cell control. It provides for operator override, processes data, acts as a functional/maintenance/safety monitor, and stores and controls all internal and external data flow. The computer's inspection data base would be manually preprogrammed and upon completion of an inspection sequence it would store all results and print out any inspections reports as instructed.

4.1.4 MATERIAL HANDLING ROBOT

A material handling robot system will be utilized for parts transfer between the in/out station, dimensional inspection, and thread inspection stations. This robot system will also be required to act as a parts platform for the thread inspection station minimizing the requirement for dedicated worksurface tooling.

4.1.5 SAFETY SYSTEM

The inspection cell shall have a safety system that will automatically shut down all operations in areas accessible by operating robots when entered by any person.

4.2 OPERATIONAL INSPECTION SEQUENCING

During the initial development phase it will be assumed that all part fixturing will be manually loaded into each station of the inspection cell. Typical sequence of events for a part requiring both dimensional and tapped hole inspection is summarized below and presented in the flow charts of Figure 5,6 and 7.

END-OF-ARM TOOLING

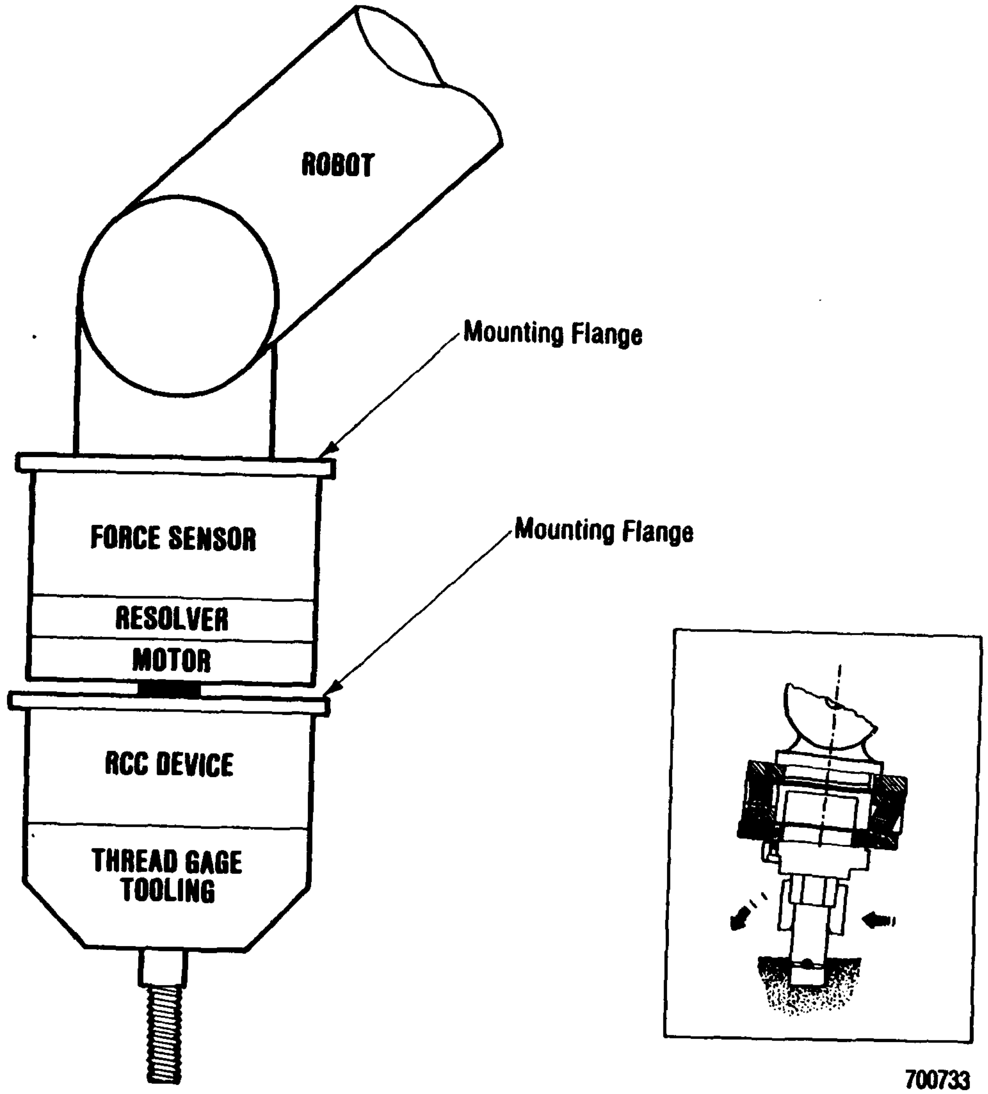


Figure 4

Inspection sequence:

4.2.1 Primary computer is loaded with a program (via CAD or manually).

4.2.2 Application program required for dimensional inspection is downloaded to the dimensional inspection station System Control Unit. The part is transferred to the X-Y platform part fixturing by the material handling robot.

4.2.3 The dimensional inspection sequence is started.

4.2.4 Prompting of the material handling robot by the computer will be desired if part orientation changes are required.

4.2.5 After inspection of the part is complete, data is transferred back to the primary computer. Actual measurements, not desired measurements, for center-to-center distances of tapped holes may be transferred to the thread inspection station controller. (Actual dimensions will minimize control loop feedback requirements.)

4.2.6 Parts are then transferred from the dimensional inspection station and refixtured onto the thread inspection working surface (or held by material handling robot).

4.2.7 The tapped hole inspection sequence is started.

4.2.8 Robot will select proper thread gage per downloaded application program.

4.2.9 Robot will center tooling with tapped hole. Robot may utilize actual measured values from the dimensional station to minimize positional corrections. Located on the hand of the robot is a 6-axis force sensor which in addition to measuring torque can sense the required compliance (see Figure 4 insert) to reposition the robot. This will minimize any binding experienced by the tooling and thereby give truer torque measurements.

4.2.10 When centering of the thread gaging and tapped hole is accomplished, the drive motor will be commanded to reverse rotate for 1.5 turns. This will insure that the gage and the part being inspected are not cross-threaded.

4.2.11 Thread gaging beings. Gage is driven into part while torque is monitored.

4.2.12 Should gage meet resistance (increase torque), motor would be commanded to stop. Depending on whether the gaging is "go" or "no-go" a decision would have to be made. If a "go" gage is used the system would reverse and count the number of revolutions it takes to extract the tooling, thus determining the thread length. If a "no-go" gage is used, it should meet resistance by the third entry revolution. (The system will be required to inspect eight standard and helicoil thread sizes per part [#2,#4,#6,#8, 2 @ #10, 2

@1/4"] with each possibly being a Class 2 or Class 3 thread. A "go" and "no-go" gage is required for each condition [64 gages total].)

4.2.13 Material handling robot prompting by the controller will be desired if part orientation changes are required.

4.2.14 After completion of a particular gage size inspection sequence the controleer will command a tool change and the inspection process continues until the part is fully inspected.

4.2.15 After part inspection is complete, all data is transferred from the controller to the primary computer, and an inspection report printout for the part is then made.

4.3 SYSTEM OPTIONS

The operational sequence previously presented assumes a part to be 100% inspected for both dimensions and tapped holes. The occurance may arise where only a dimensional inspection or tapped hole inspection will be required, or only a percentage of that operation will want to be executed. For this reason part dimensions/tapped holes will want to be coded or characterized so as to facilitate this type of inspection procedure.

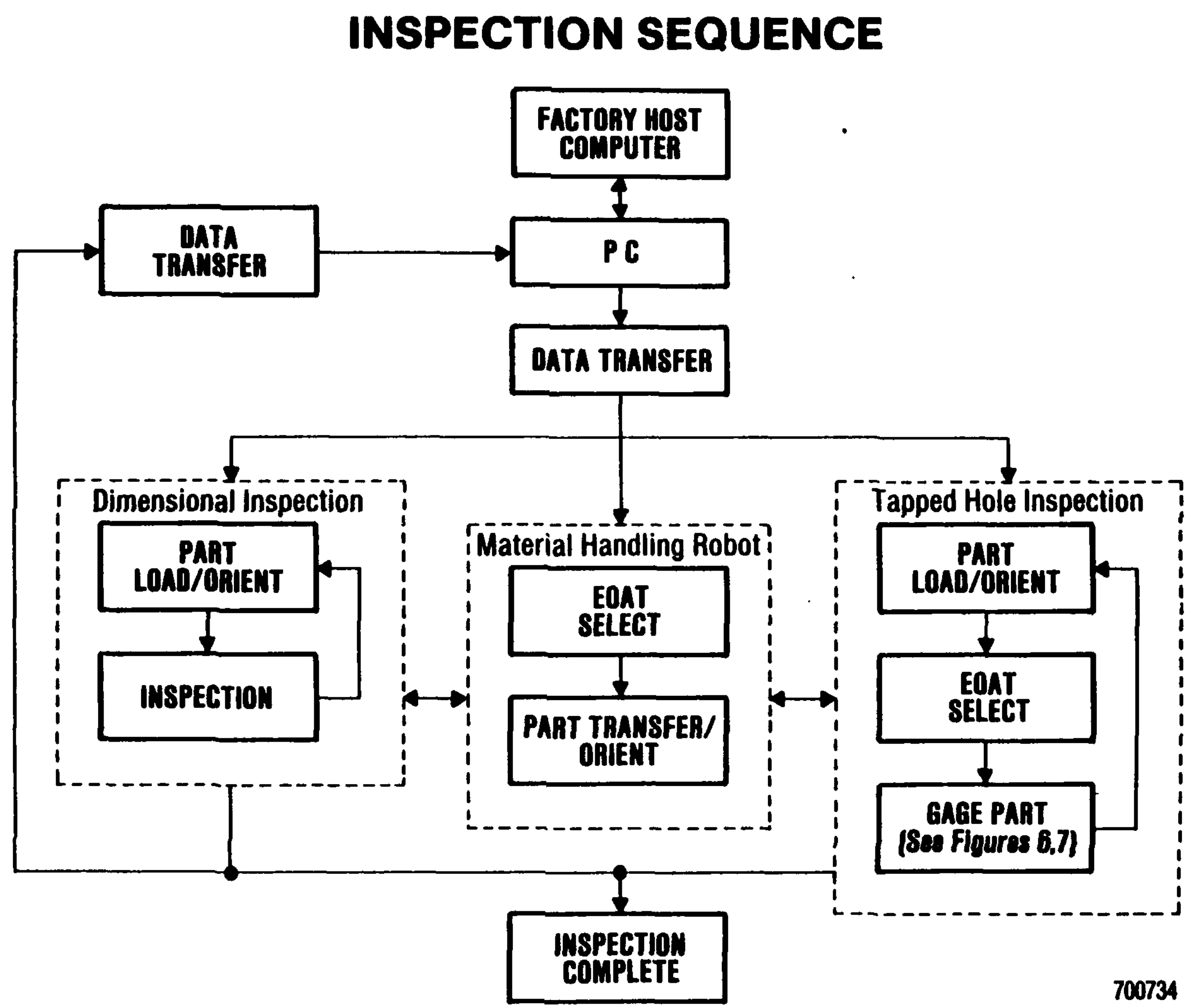

INSPECTION SEQUENCE
FACTORY HOST COMPUTER
P C
DATA TRANSFER
DATA TRANSFER
Dimensional Inspection
PART LOAD/ORIENT
INSPECTION
Material Handling Robot
EOAT SELECT
PART TRANSFER/ ORIENT
Tapped Hole Inspection
PART LOAD/ORIENT
EOAT SELECT
GAGE PART (See Figures 6,7)
INSPECTION COMPLETE
700734

Figure 5

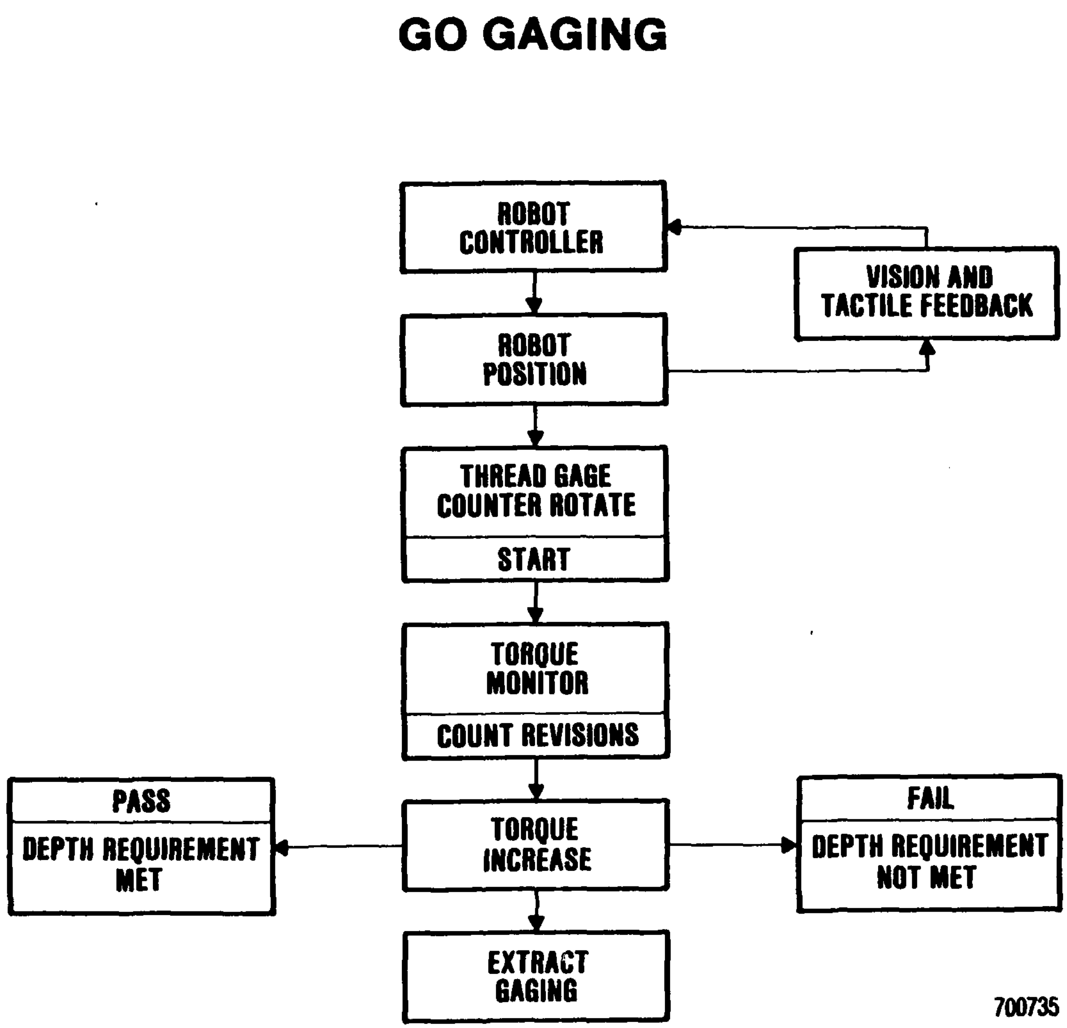

GO GAGING
ROBOT CONTROLLER
VISION AND TACTILE FEEDBACK
ROBOT POSITION
THREAD GAGE COUNTER ROTATE
START
TORQUE MONITOR
COUNT REVISIONS
PASS
DEPTH REQUIREMENT MET
TORQUE INCREASE
FAIL
DEPTH REQUIREMENT NOT MET
EXTRACT GAGING
700735

Figure 6

NO-GO GAGING

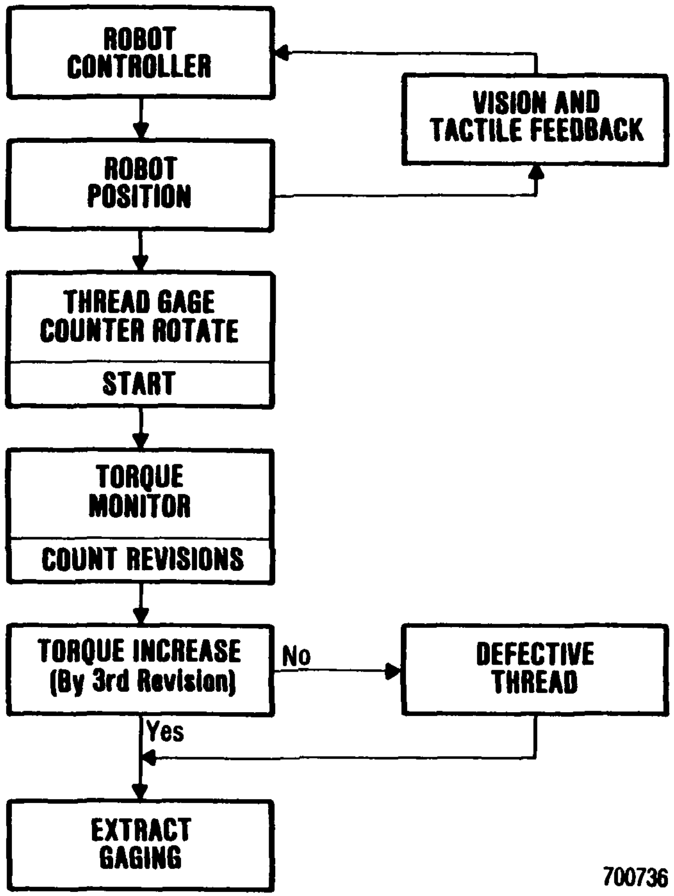


Figure 7

5.0 EQUIPMENT SELECTION

Based on the proposed technical approach equipment requirements were next addressed. It was determined that four specific pieces of equipment were necessary to initiate the project. Since a final cell configuration would be dependent upon testing of this equipment, and integration of any hardware purchased into the final concept was desireable, all hardware was required to meet the most stringent specifications. These initial equipment requirements were:

1. Dimensional Inspection Machine

2. Robot

3. Six Axis Force Sensor

4. System Supervisory Computer

5.1 DIMENSIONAL INSPECTION MACHINE

At the time this survey was performed only two vendors were manufacturing equipment meeting the requirements of the project:

Rank Videometrics
411 Jarvis Ave.
Des Plaines
Ill. 60018
312-297-7720

View Engineering
1650 N. Voyager Ave.
Simi Valley, Ca. 93063
805-522-8439

Primary considerations regarding equipment selection were:

1. Operation Envelope: 18 x 18 x 6 (X,Y, Z)
2. Menu Driven
3. Accuracy - ± .0025 inches (All Axes)
4. Supplier Support
5. Price
6. Peripheral Options

Based on available information and vendor communications a matrix comparing options and support was generated. See Figure 8. A final decision to select the View Engineering Model 1200 non-contact 3-dimensional measuring system was justified primarilly on its thermal compensation, maturity of the product line (4 years) and the fact that GM is a partial owner in the company. It was felt that View's relationship with GM would gain additional leverage should modification of the equipment be required.

DIMENSIONAL INSPECTION EQUIPMENT COMPARISON MATRIX

	ACCURACY	STANDARD ELECTRONICS SUPPLIED	MAP COMPATIBILITY	MISC	PRICE
RANK VIDEO-METRICS	X-Y-Z ± .00025 @ 68°F ± 2°	• 768k Memory • 12" CRT • 2 Flex 3.5" Disk Drives (1.2 MByte) • Printer • Keyboard	Uses Hewlett Packard and Computer/ Processor. Hardware for Map Interface Available within 1.5 Years	Current Model Redesigned within the Last Six Months	$143,750 (Quotation No. 2413, 2414, 2415)
VIEW ENGINEERING	X-Y ± .0016 Z ± .0025 @ 68°F + 22°	• 1 MByte Memory • 12" CRT • 2 Flexible 5¼" Disk Drives (680k) • 10 MByte Winchester Disk • Printer • Keyboard	Uses Custom View Processor Based on Intel Multibus. Map Hardware Available Today	Fourth Year in Production GM Owns 30% of Company	Approximately $170,000 (150K Base Price Plus Options)
REMARKS	Thermal Errors of Rank System if Operated Over View Spec Could be as Large as .002-.003 Inches		Map Interface with ITM-Project 12 Host Computer is a System Requirement	View Will Support ITM Project Technically Due to GM Partnership	Based on Equivalent Options and Standard Equipment Available

700941

Figure 8

5.2 ROBOT

At the time this survey was performed only two vendors manufactured a robot with an advanced controller design: GMF Robotics and ADEPT. Unlike other manufacturers controllers these featured self-diagnostics, full program and edit capability, menu driven software, analog and digital I/O capability, and high level programming languages. At the time the robot selection was being addressed there existed two applilcations. One for material handling, and the second for thread inspection. ADEPT'S design lent itself only to thread inspection while GMF'S product line could support both. (ADEPT built only one robot at that time.)

If thread inspection were to become a reality it would be desireable to have common equipment. For this reason GMF'S S-100 robot and Karel controller were selected. This robot was designed for use as a material handling platform. However, for development purposes it could be used on an interim basis for determining if thread inspection end-of-arm-tooling was robot compatible.

5.3 SIX-AXIS FORCE SENSOR

At the time this survey was performed only three vendors were manufacturing six-axis force sensors. These were:

Barry Wright Corp.
700 Pleasant St.
Watertown
Mass. 02172
Model FS6-120A

Lord Corp.
407 Gregson Dr.
Cary
N. Carolina 27511
919-469-2500
Model F/T-15/50

JR INC
22 Harter Ave. #13
Woodland
CA. 95695
Model VFS-3A15

All these devices are similar in construction and are specifically made for robotic applications. They are based on strain technology and allow the user to monitor force and torque reactions in + or - X,Y and Z directions, hence six axes. Generally all units are available in varying levels of sensitivity, however for our application, due to the delicate nature of thread gaging, a resolution of .05 in -oz in torque was desired. At the time all vendors were advertising a .15 - .20 in-oz resolution. Another feature absolutely required for laboratory testing was an analog output capability. Ater reviewing these requirements with suppliers, all felt they could fine tune an off-the-sheif unit to meet the torque sensitivity requirements. However, only JR3 could supply the analog output at no extra charge. For this reason the JR3 force/torque sensing system was selected.

5.4 SYSTEM SUPERVISORY COMPUTER (SSC)

Selection of the SSC was facilitated through use of an evaluation matrix, which was designed to aid in the comparison of several candidate systems. The selection issues used for comparison included:

- system bus standard
- system CPU type
- type of system memory
- operation systems supported
- available programming languages
- data communications interfaces
- DSO experience with candidate system
- type and availability of training
- availability of maintenance support
- price
- vendor's ability to deliver
- overall match with project needs

The vendors considered were:

- Digital Equipment Corporation
- Hewlett Packard
- Intel
- Motorola
- International Business Machines

Additionally, it was required that the hardware and software solutions be implemented by using of-the-shelf products. An intangible factor, best described "as the perceived abililty and willingness of the vendor" to help satisfy project goals throughout the life of the project, also entered into the final selection. The system selected was the Intel 310 microcomputer.

6.0 EQUIPMENT SPECIFICATIONS

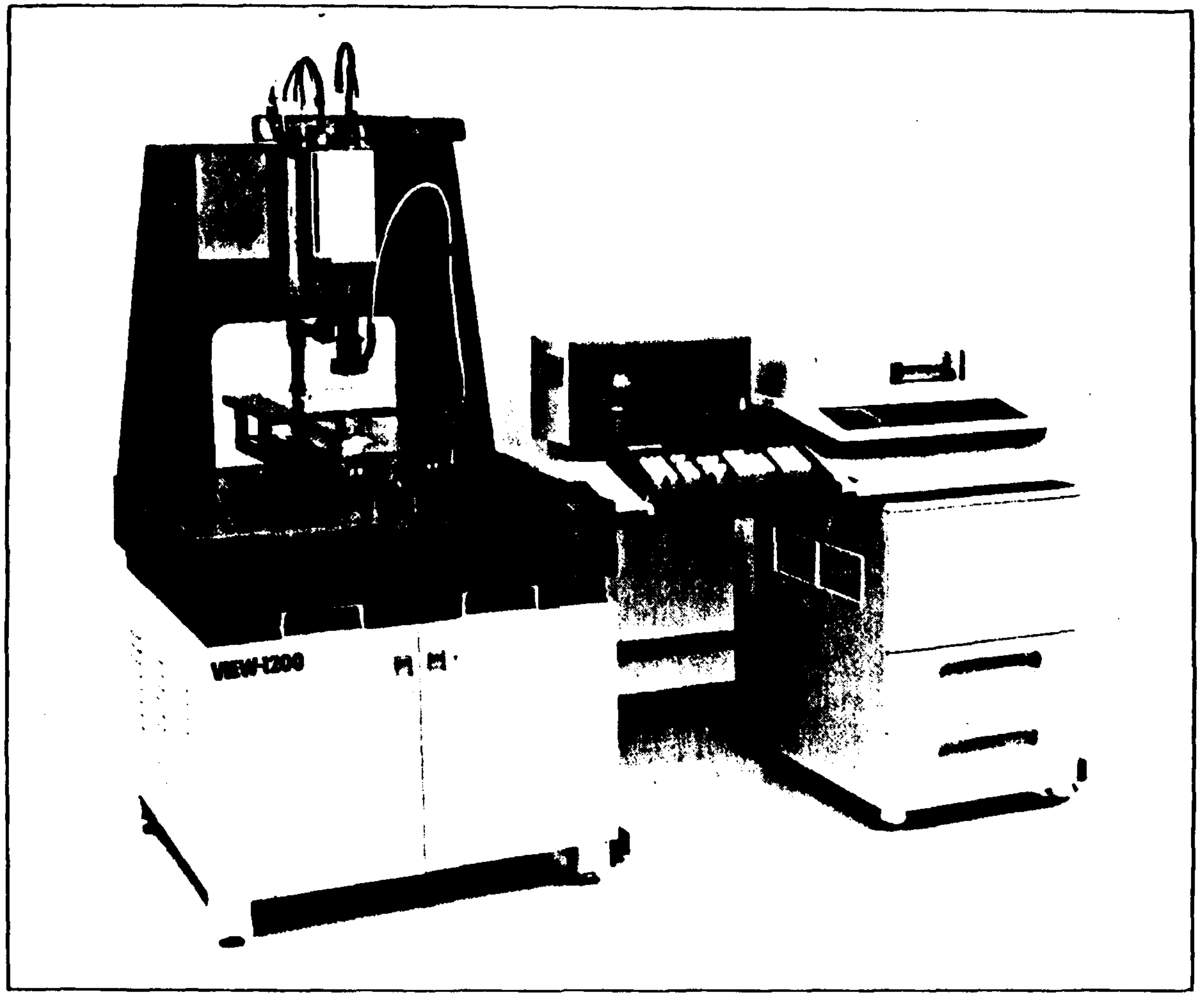
6.1 DIMENSIONAL INSPECTION MACHINE

The View Engineering Model 1200 (Figure 9) is a 3 - dimensional non-contact measuring system. It has a working envelope of 18 x 24 x 6 (X,Y, Z) inches in addition to a fourth rotational axis that was orginally designed to mount and turn symetrically manufactured (Lathed) parts. The system is delivered with four lenses (16mm, 38mm,50mm,75mm) allowing the user to select an operating accuracy depending on the application involved. Using the system's most accurate lens a system accuracy of .0004 inches in X,Y and Z axes can be attained. See Figure 10 for other available accuracy specifications.

The system utilizes an X - Y servo-motor-driven table with a camera mounted in the Z-axis. Since the X and Y dimensions are in the same plane, the planar dimension is established by the distance the table travels plus the camera's interpretation of the edge of the surface feature being inspected. A built-in algorithm establishes the planar dimension that has been checked. The dimension along the Z-axis is a function of the focal length of the camera. One plane is established as the zero or reference point, with the depth being a new plane requiring a new focal length. The distance the fixed focal length camera moves along a Z axis determines the Z dimension of the part feature being examined. Lens selection is determined by part feature tolerances to be inspected. Because each lens has a different field-of-view (.01 to .20 in.) and the system is preprogrammed to move to a nominal location to acquire an image (edge of feature), it is necessary to match the field-of-view with the allowable part variance (due to part tolerance). Search routines do exist, to a limited degree, to "look" for the feature outside the field-of-view. Since the vast majority of mechanical parts produced at Delco are more critically toleranced, all testing performed used the most accurate lens (16mm.)

6.2 ROBOT

The GMF S100 Robot selected is a six-axis anthropomorphic device manufactured for material handling and medium accuracy assembly applications (see Figure 11 for Illustration: Manufacturers Specifications). It's unique human-like configuration allows it to operate in both spherical and cartesian coordinate systems. Optional equipment included a 16 channel A/D converter card for use in digitizing force sensing electronics.



VIEW 1200

Figure 9

VIEW 1200 ACCURACY SPECIFICATIONS

LENS FOCAL LENGTH	X & Y AXIS			Z AXIS (All)
	12 x 12	12 x 18	18 x 18	
16mm	±0.00016 In	X - ±0.00016 In Y - ±0.00040 In	±0.00040 In	±0.00025 In*
34mm	±0.00025 In	X - ±0.00025 In Y - ±0.00050 In	±0.00050 In	**
50mm	±0.00042 In	X - ±0.00042 In Y - ±0.00066 In	±0.00066 In	**
75mm	±0.00066 In	X - ±0.00066 In y - ±0.00090 In	±0.00090 In	**

* Determined using Starrett-Weber <u>CROBLOX</u> gage blocks.
** Accuracy with other lenses depends on optical depth of focus.

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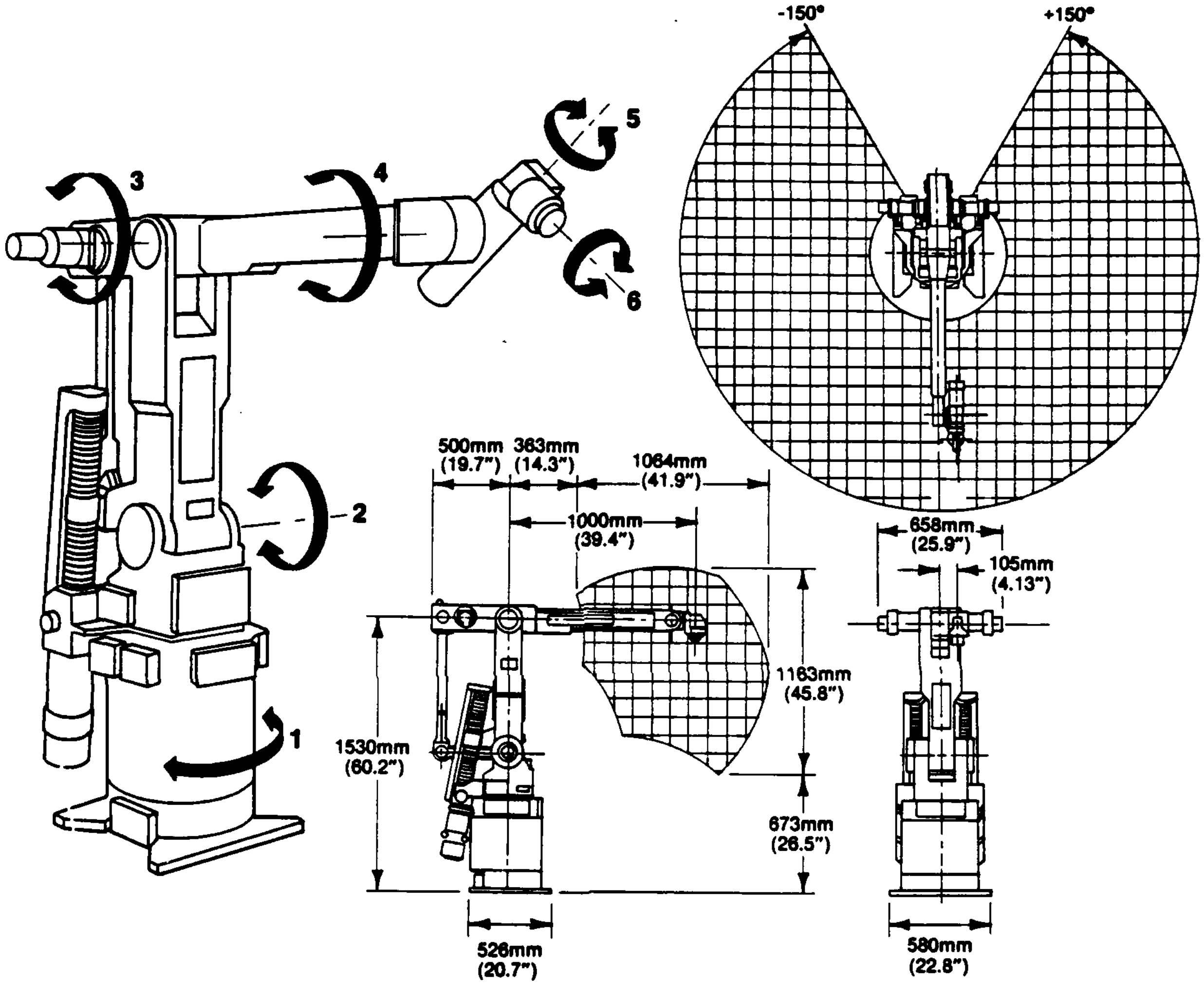
Figure 10

GMF S100 ROBOT

DIMENSIONS



CAPACITIES

Loading capacity at wrist mounting surface at maximum speed and extension:

6-Axis Model:

Standard type: 10kg (22 lbs)
High Speed Type: 5kg (11 lbs)

5-Axis Model: 10kg (22 lbs)

Repeatability: ±0.2mm (±0.008") at maximum speed and extension

Approximate weight:
Mechanical unit = 350kg (770 lbs)

6-AXIS MODEL

AXIS	DESCRIPTION	RANGE	SPEED Standard	SPEED High Speed
(1)	Base rotation	300°	90° per sec	90° per sec
(2)	Waist bend	85°	90° per sec	90° per sec
(3)	Shoulder bend	65°	90° per sec	90° per sec
(4)	Wrist pitch	190°	120° per sec	240° per sec
(5)	Arm roll	360°	120° per sec	240° per sec
(6)	Wrist roll	340°	120° per sec	300° per sec

5-AXIS MODEL

AXIS	DESCRIPTION	RANGE	SPEED Standard
(4)	Wrist pitch	250°	240° per sec
(5)	Wrist roll	380°	380° per sec

700943

Figure 11

6.3 SIX-AXIS FORCE SENSOR

The JR3 Force Sensor selected (Model UFS-3A15, see Figure 12) was a specially modified off-the-shelf device. Modifications made at the factory enhanced the system's resolution from 0.15 in-oz to .05 in-oz. otherwise, the system's specifications are as follows:

- JR3 monolithic six-degree-of-freedom force sensor
- sensor cable (connects JR3 sensor to JR3 electronics enclosure)
- JR3 Intelligent Support System (JR3 sensor to JR3 electronics enclosure which contains):
- signal conditioning board
- data acquisition board
- processsor board

Foil strain gages on the JR^3 sensor body are excited by voltage through the sensor cable from the electronics enclosure. Millivolt analog signals from the sensor are carried back to the electronics enclosure via the sensor cable. The sensor cable's foil shielding is driven at a guard voltage to increase noise rejection.

The JR^3 signal conditioning board amplifies and filters the raw analog signals, then transmits them to the JR^3data acquisition board where the signals are digitized (12 bit A/D). Digital data is then transmitted to the JR^3 processor board, processed (cross sensitivity removal, digital filtering, load envelope monitoring, tare weight removal, etc.) and made available for output. The processsor board also watches for, and acts upon, input commands. The six channels of un-decoupled analog signals are also output through a nine-pin port.

Onboard shunt resistors combined with full scale checking/calibration software offer automatic drift compensation upon the receipt of the proper command.

The JR^3 sensor requires the power supplies listed below. Each is shown with the particular portion of the electronics it powers.

+5V	2A	digital power (microprocessor, etc)
+15V	300mA	analog power (bridge amplifiers, reference voltages, etc.)
-15V	300mA	analog power
+12V	75mA	serial communication, shunt relays
-12V	75mA	serial communication

The six channels of analog outputs are in the ± 10 volt range with +10 volts at +100% of full scale load and -10 volts at -100% of full scale load. Within a certain range, the user may set the desired full scale values via gain adjust. Setting the full scale

JR3 UNIVERSAL FORCE-MOMENT SENSOR SYSTEM

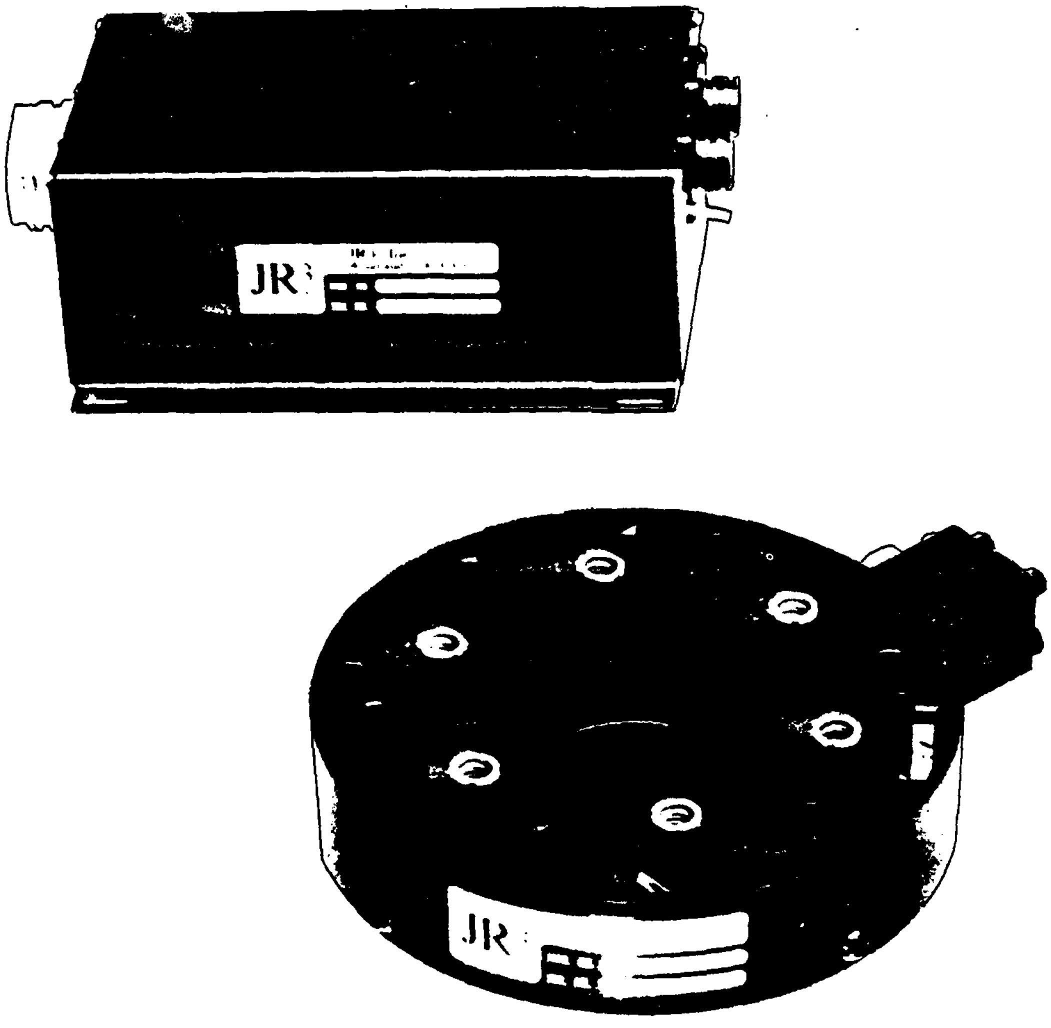


Figure 12

for larger loads allows the user to read overloads; setting the full scale for smaller loads enhances resolution.

The discrete I/O port consists of:
- eight discrete bits of input: four are used to enable load envelopes; one triggers a soft reset; one resets the offsets; and one is not currently used.
- eight bits of output - seven user-definable flags for load envelope trip points and error flag plus the safety strobe.
- hard reset - hardware reset of processor.
- digital ground.

Two RS232 serial ports are provided (port A & B) which can be used for inputting commands, data transmission, error monitoring, threshold monitoring, etc. Data format through each serial port is controlled by commands entered through that port. The only difference between ports A & B is that port B will begin a baud rate detection routine upon receipt of a "break" signal; port A ignores the "break" signal. Default serial communication parameters (from factory) on powerup are: 9600 baud, 8 data bits, no parity, 1 stop bit.

6.4 SYSTEM SUPERVISORY COMPUTER (SSC)

6.4.1 SSC HARDWARE

The system selected to function as the system supervisory computer is an Intel system 310 microcomputer. Its characteristics include:

- a seven slot card cage, suitable for addition of various data communications controller boards
- an 80286 based, 16 bit processor
- multi-user and multi-tasking capability
- priority interrupt logic
- hardware system clock
- 1 megabyte of RAM storage
- 1 parallel port connector
- 2 serial port connectors
- 1 flexible 5-1/4 inch double sided, double density disk drive
- 1 40 megabyte Winchester disk drive

The Intel system 310 has proven to be compatible with all SSC oriented project requirements.

6.4.2 SSC SOFTWARE

The operating system selected was Intel's iRMX 86. It's major features include:

- real-time capability
- concurrent running of multiple tasks
- priority-based scheduling
- interrupt-driven processing
- device-independent I/O capability

The iRMX 86 operating system is configurable through use of a supplied interactive configuration utility program. Various programming languages were available, and PL/M-86 was selected for project use. PL/M-86 is a high-level, block structured language which has many useful features.

7.0 ENABLING TECHNOLOGY DEVELOPMENT

This section of the report will primarilly address testing as related to thread inspection and material handling. Because the vision system used for dimensional inspection was an off-the-shelf technology no enabling technology testing was required in this area. Some material handling concepts were tested as related to group technology and will be discussed in lesser detail. The results of these experiments would be used to further solidify the inspection cell's final configuration.

7.1 THREAD INSPECTION (INTERNAL)

7.1.1 BACKGROUND

Gaging of internal screw threads is the process of investigating the extent to which they conform dimensionally to prescribed limits of size. This inspection process is accomplished using go and no go gaging that is physically threaded into the product thread.

The maximum-material-limit, or go gage, verifies the extent of the tolerance as applied to a specific thread in the direction of the limit of maximum material and represents the minimum limit of internal threads. The ideal go gage is a threaded counterpart of the internal thread, made exactly to its prescribed dimensions. These gages most nearly duplicate the assembly conditions of threads.

The minimum-material-limit gages, or no go, control the extent of the tolerance in the direction of the maximum limit of internal threads. Again it is a threaded counterpart of the internal thread, however does not represent assembly conditions.

The application and maintenance of thread gaging is defined in FED-STD-H28. In short the usage of thread gaging to verify product conformance is very subjective. Because it is not practical, or possible, to control nor limit the torque applied by operators, or even that used by a specific operator at various times and under varying conditions, the following standard practice has been adopted with respect to permissible gage entry:

Go gages must completely enter the product internal thread provided a definite drag from contact with the product material does not result.

No Go Gages acceptability is applied to the product internal thread if it does not enter, or if a definite drag from contact with the product material results on or before the third turn of entry. Obviously the term "Definite Drag" is subjective and will vary from operator to operator.

7.1.2 TESTING

In order to develop an automated thread inspection process, it was necessary to determine quantitatively what the "Definite Drag" limit would be for each thread size. Using internally threaded samples (steel and aluminum) mounted to the JR^3 force/moment sensor, inspection operators normally assigned thread inspection tasks were tested. Each operator "inspected" three samples each of 2-56, 4-40, 6-32, 8-32, 10-32, 1/4-20 and 1/4-28 size threads (see Figure 13). Class III threads were chosen to obtain a worst case situation and all testing was conducted with go gaging only. It was assumed that definite drag limits would be independent of gage type. During each sample test, running torques as well as stall torques were obtained using the JR^3 sensor analog output and a strip chart recorder. In all 27 samples for each thread size and material type were tested. Running torque data from a typical test run is shown in Figure 14 and variations in technique are apparent. Some operators continually turn the gage with both hands while others use only one hand. This can be observed by comparing running torque applitude variations. It is also apparent from the data (Figure 15) that stall torque (Definite Drag) differences did exist between operators. Averaged Torque values vs. gage size are represented in Figures 16 thru 24 for aluminum and Figures 25 thru 33 for steel, for each of the participating operators. A summary of these curves is presented in Figures 34 and 35. From this data desireable torque thresholds required for automating Go/No Go Gaging proceedures were derived. This data is presented in Figure 36 and served as a guideline throughout the thread inspection end-of-arm-tooling design phase.

7.2 MATERIAL HANDLING

Efforts concentrated on designing and testing end-of-arm tooling (EDAT) concepts capable of holding and/or transporting families of similar parts from input stations to the View 1200 where dimensional inspection would occur. The object was to identify concepts and designs that would minimize tooling requirements primarilly at the View 1200 thereby further increasing the cost payback of the proposed automated system.

As mentioned earlier the View 1200 is equipped with a fourth rotational axis. Though it was intended by the manufacturer to hold and orient lathed parts, the concept of adding a robotic gripper capable of fixturing a part seemed a more desireable solution. (See Figure 37). To successfully implement the transport and fixturing concept on an open-loop basis (no feedback) two conditions had to be met. First the gripper must be capable of handling a family of parts, not a unique part, and second it must transport them to the View 1200 with sufficient accuracy to place the part within the vision systems field of view ($\pm$.005).

TORQUE THRESHOLD TEST SETUP

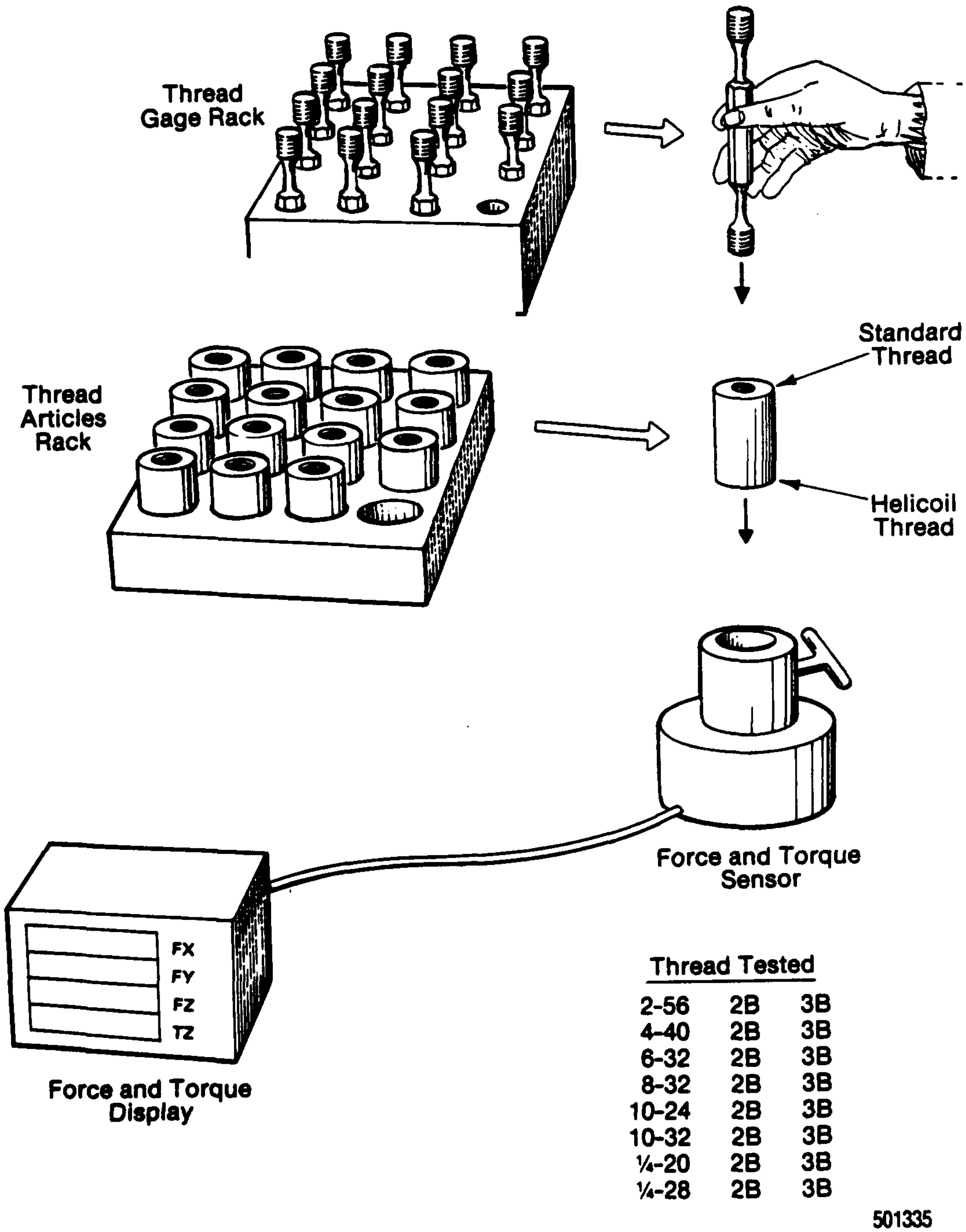


Figure 13

OPERATOR TEST DATA

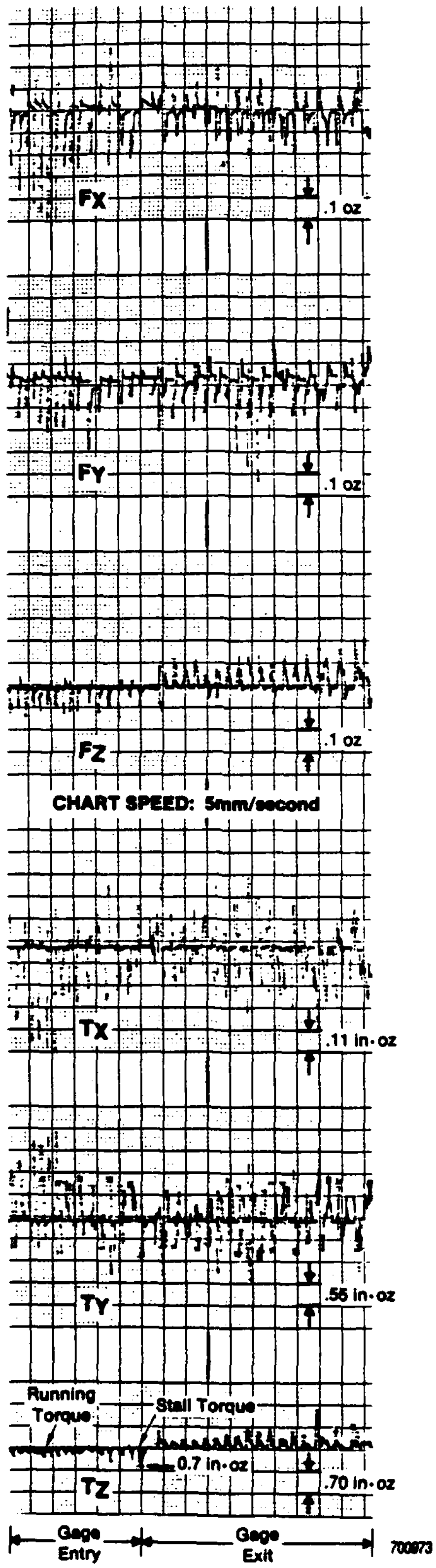


Figure 14

OPERATOR TEST DATA

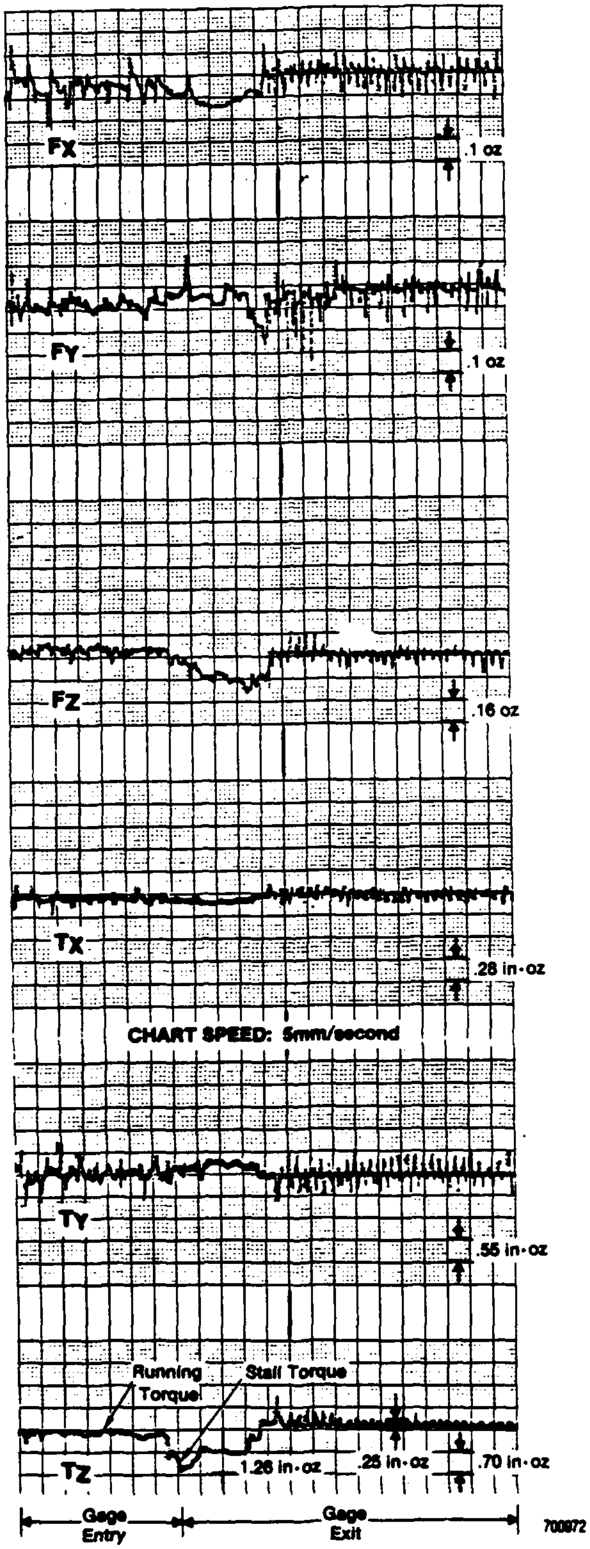


Figure 15

TORQUE VERSUS GAGE SIZE NO.1
(Aluminum Sample)

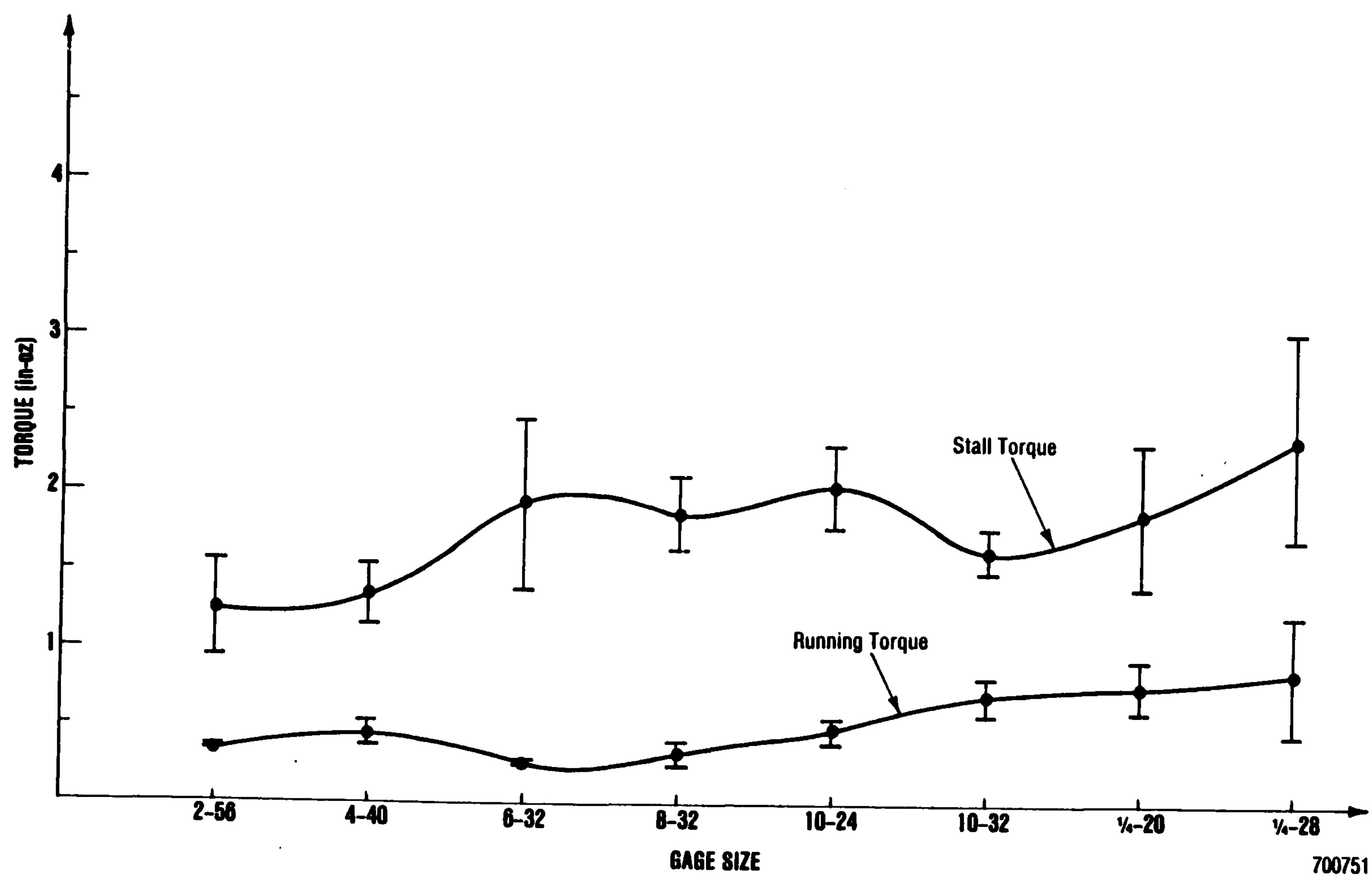


Figure 16

TORQUE VERSUS GAGE SIZE NO.2
(Aluminum Sample)

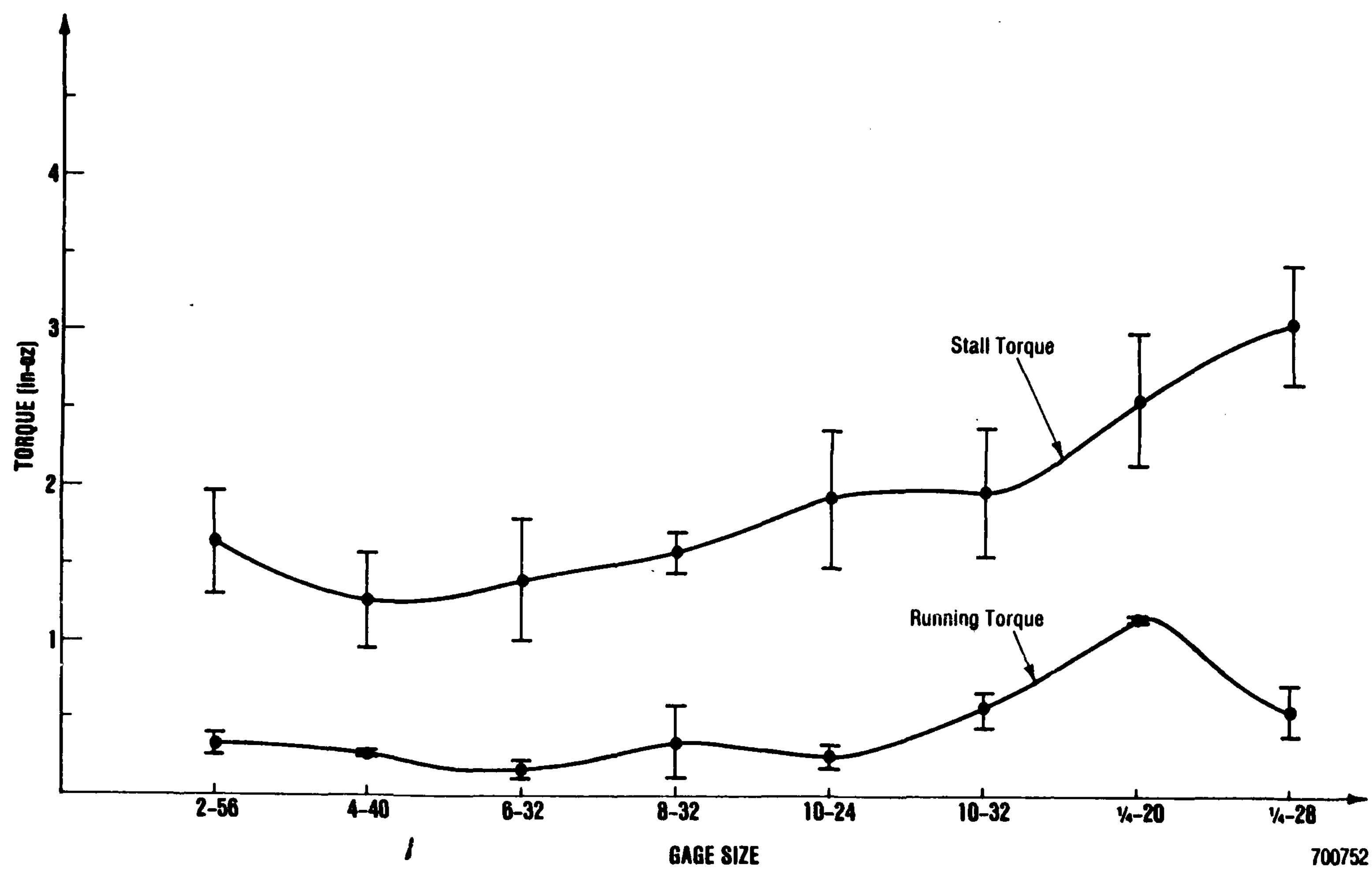


Figure 17

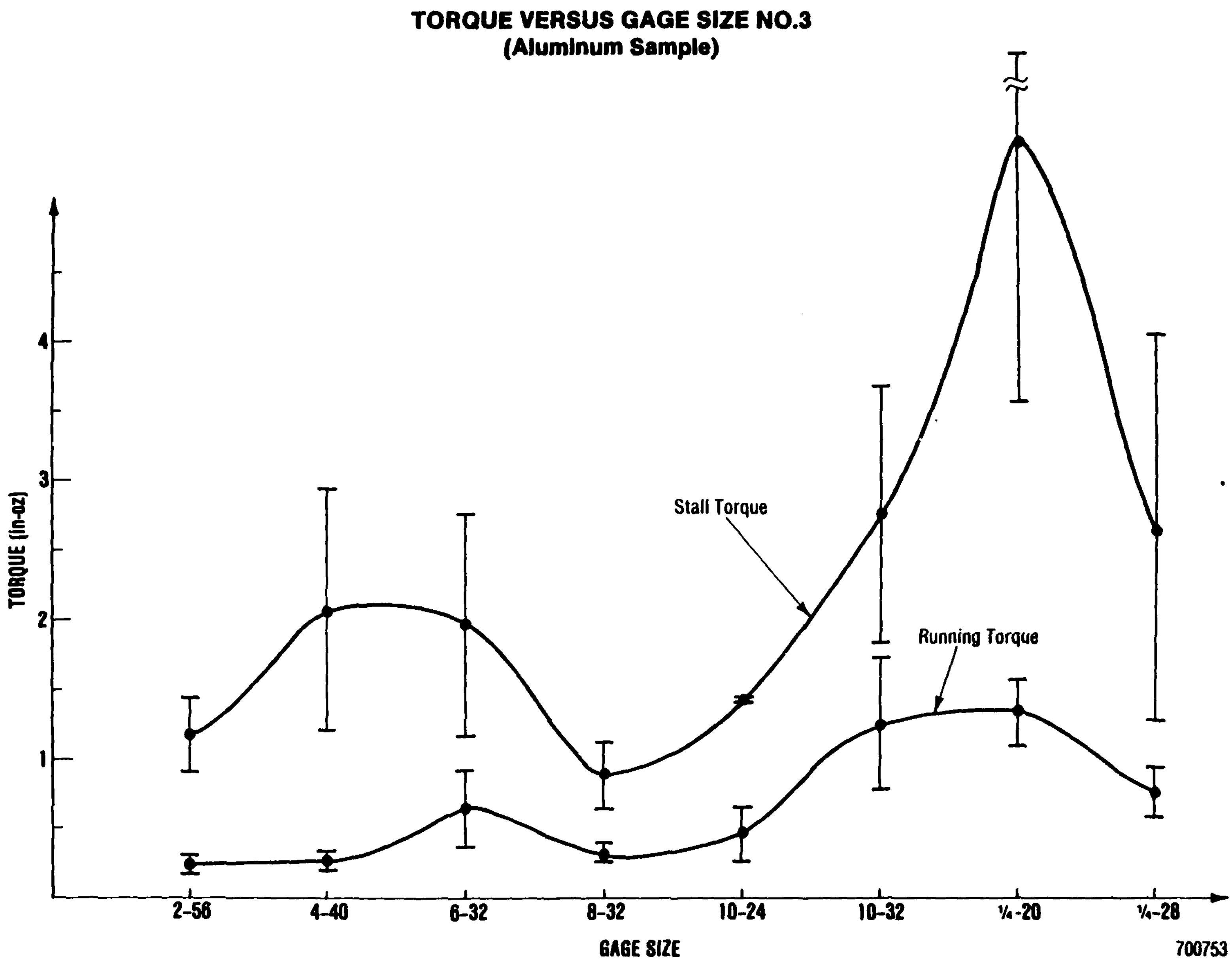

TORQUE VERSUS GAGE SIZE NO.3
(Aluminum Sample)
TORQUE (in-oz)
4
3
2
1
Stall Torque
Running Torque
2-56
4-40
6-32
8-32
10-24
10-32
¼-20
¼-28
GAGE SIZE
700753

Figure 18

TORQUE VERSUS GAGE SIZE NO.4
(Aluminum Sample)

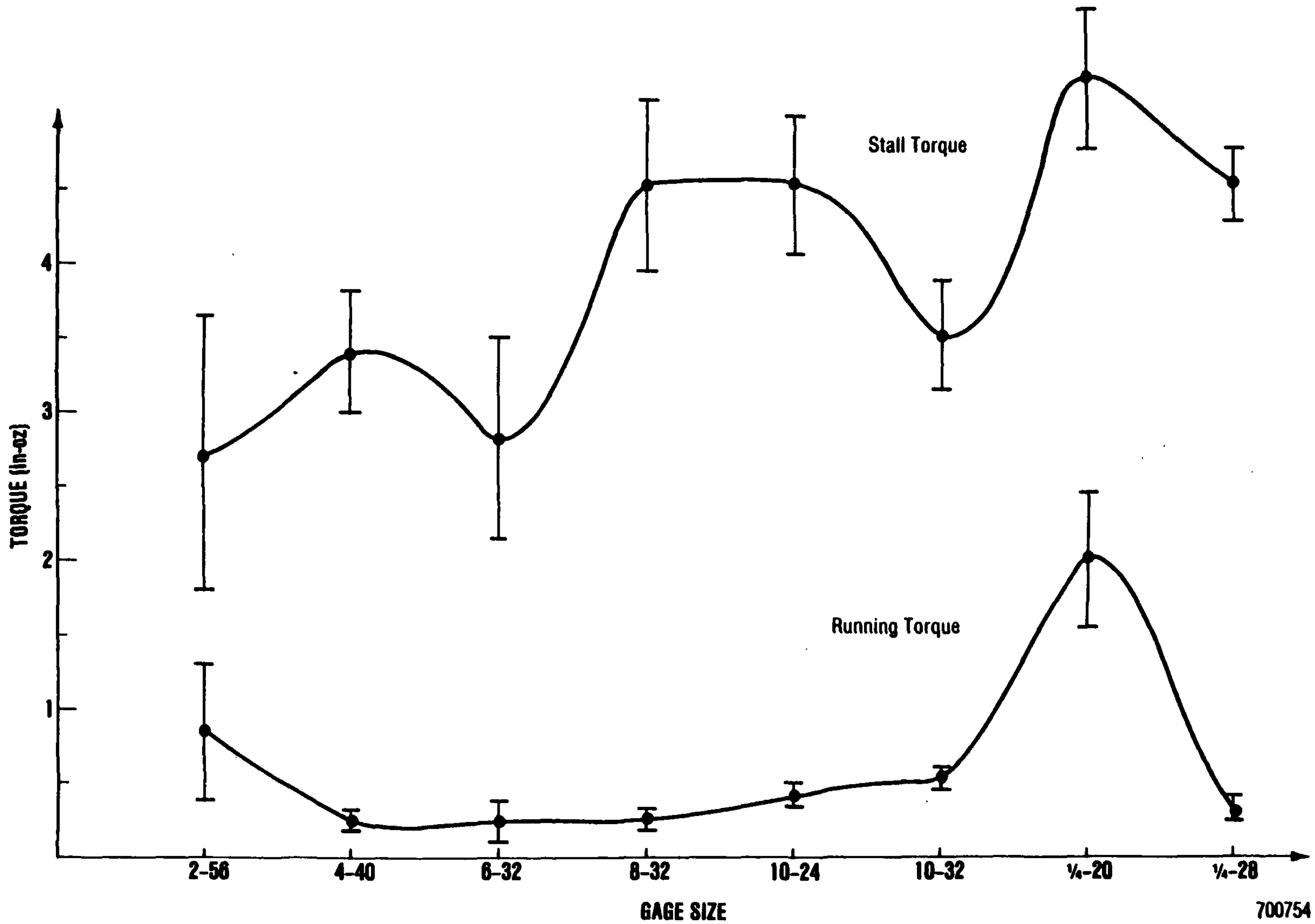


Figure 19

TORQUE VERSUS GAGE SIZE NO.5
(Aluminum Sample)

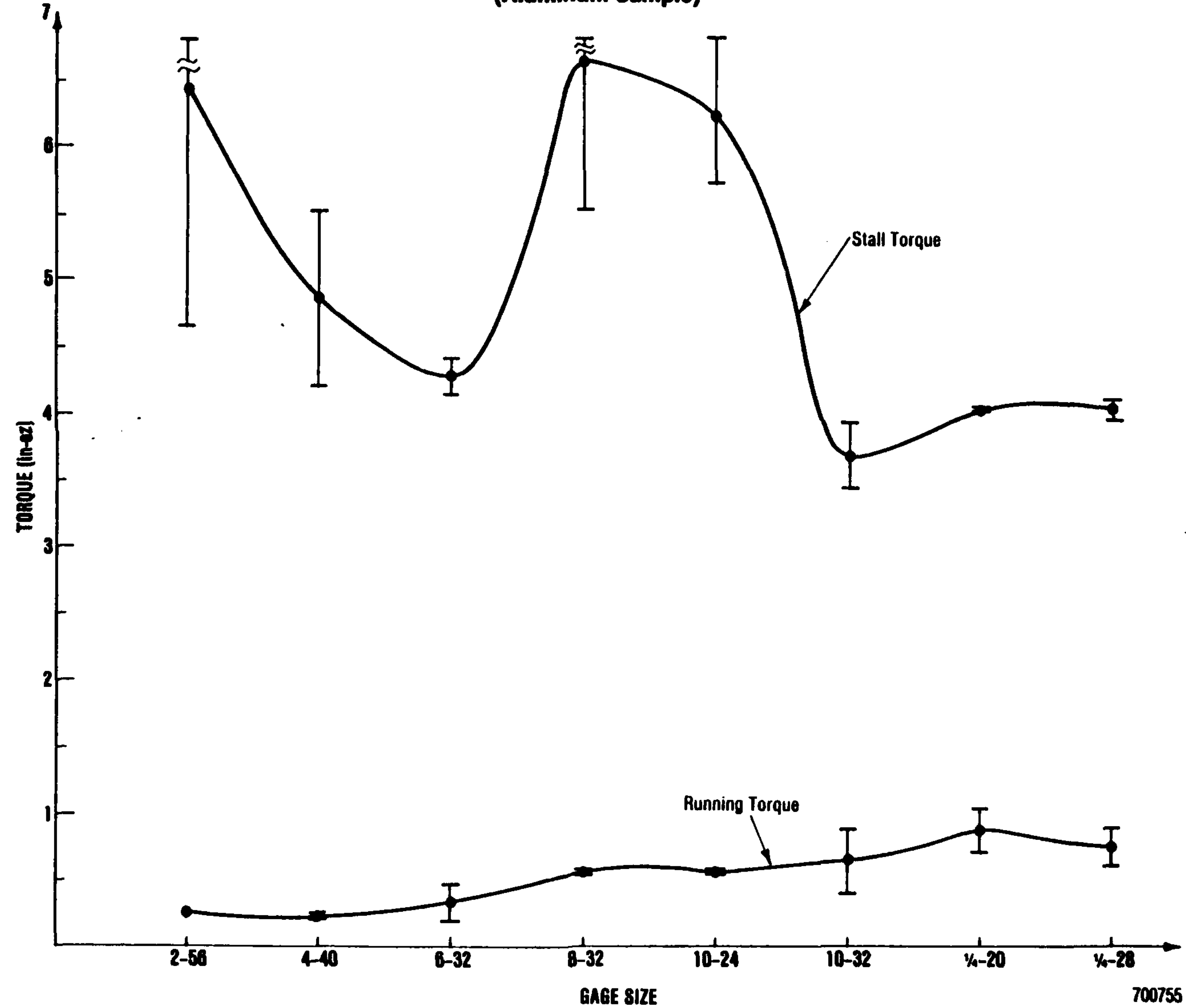


Figure 20

TORQUE VERSUS GAGE SIZE NO.6
(Aluminum Sample)

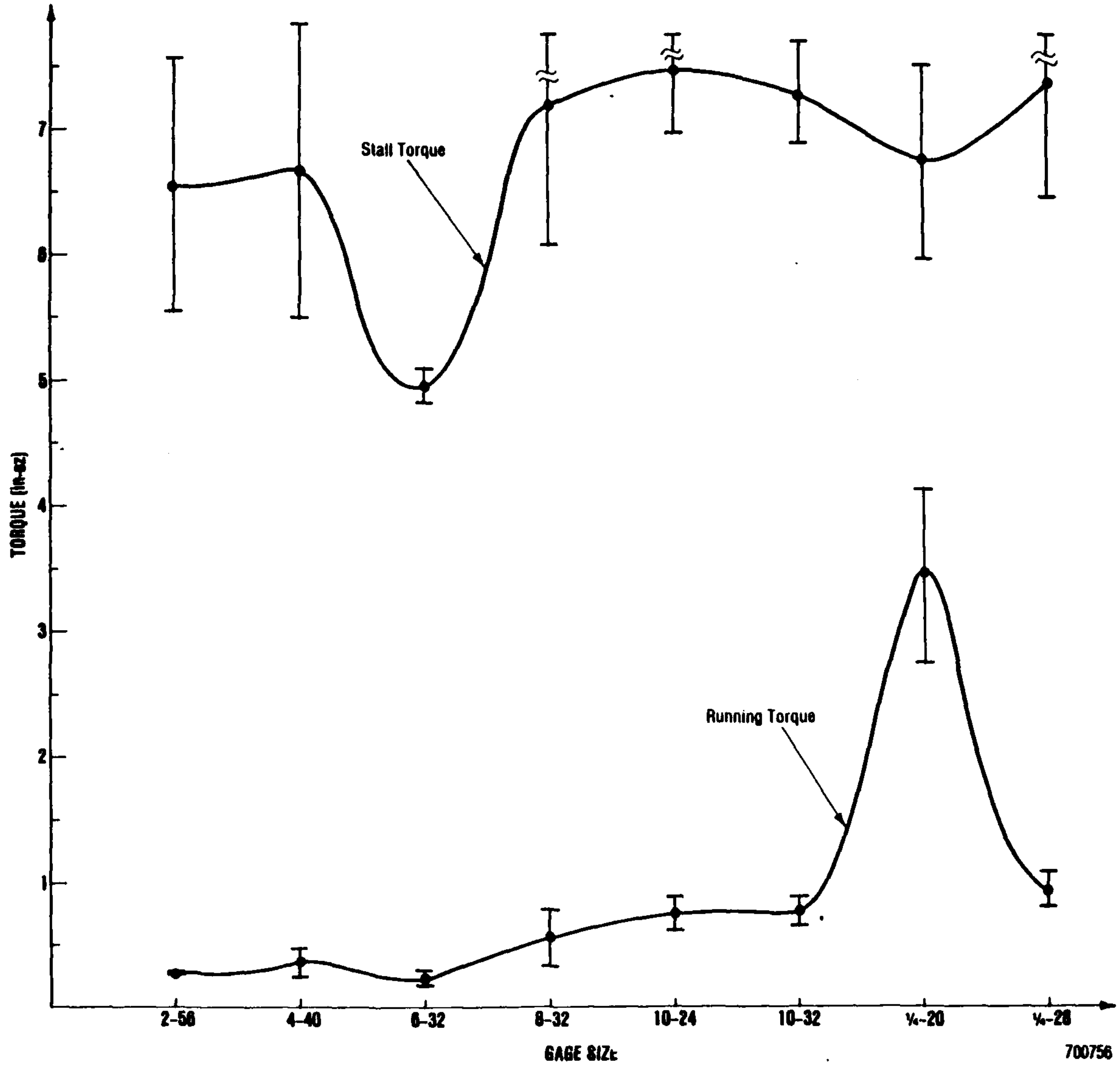
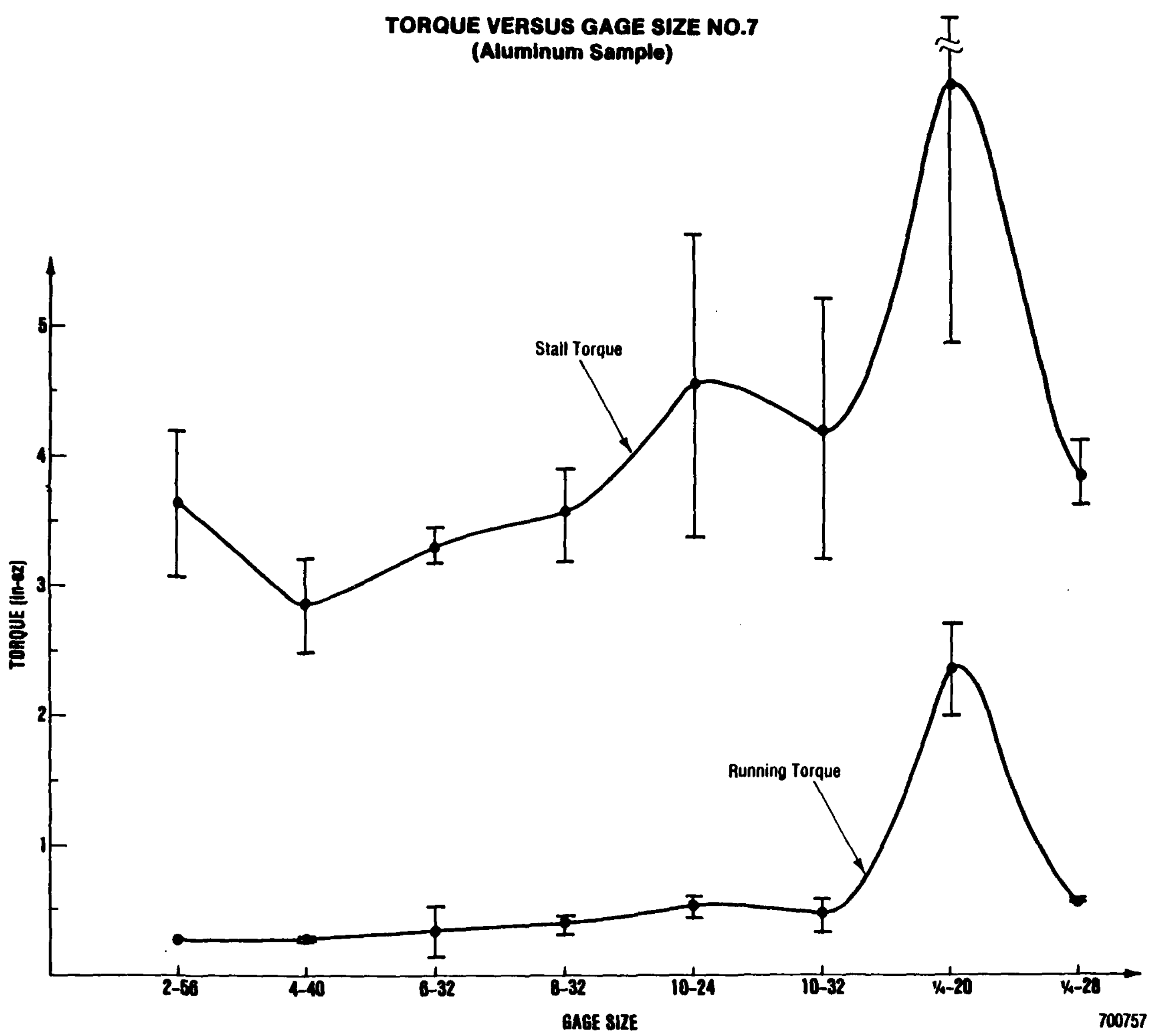


Figure 21



TORQUE VERSUS GAGE SIZE NO.7
(Aluminum Sample)
Stall Torque
Running Torque
TORQUE (in-oz)
5
4
3
2
1
2-56
4-40
6-32
8-32
10-24
10-32
¼-20
¼-28
GAGE SIZE
700757

Figure 22

TORQUE VERSUS GAGE SIZE NO.8
(Aluminum Sample)

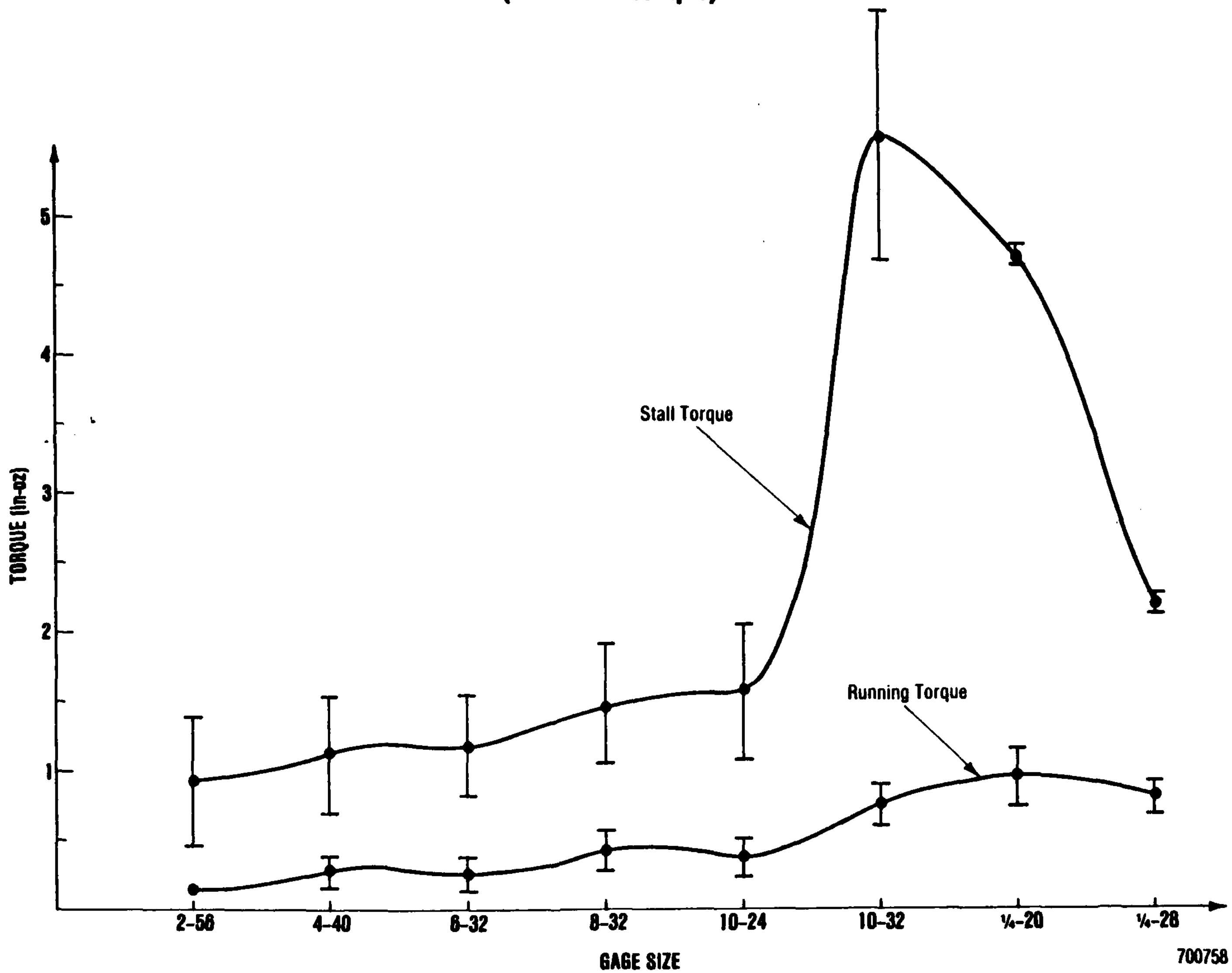


Figure 23

TORQUE VERSUS GAGE SIZE NO.9
(Aluminum Sample)

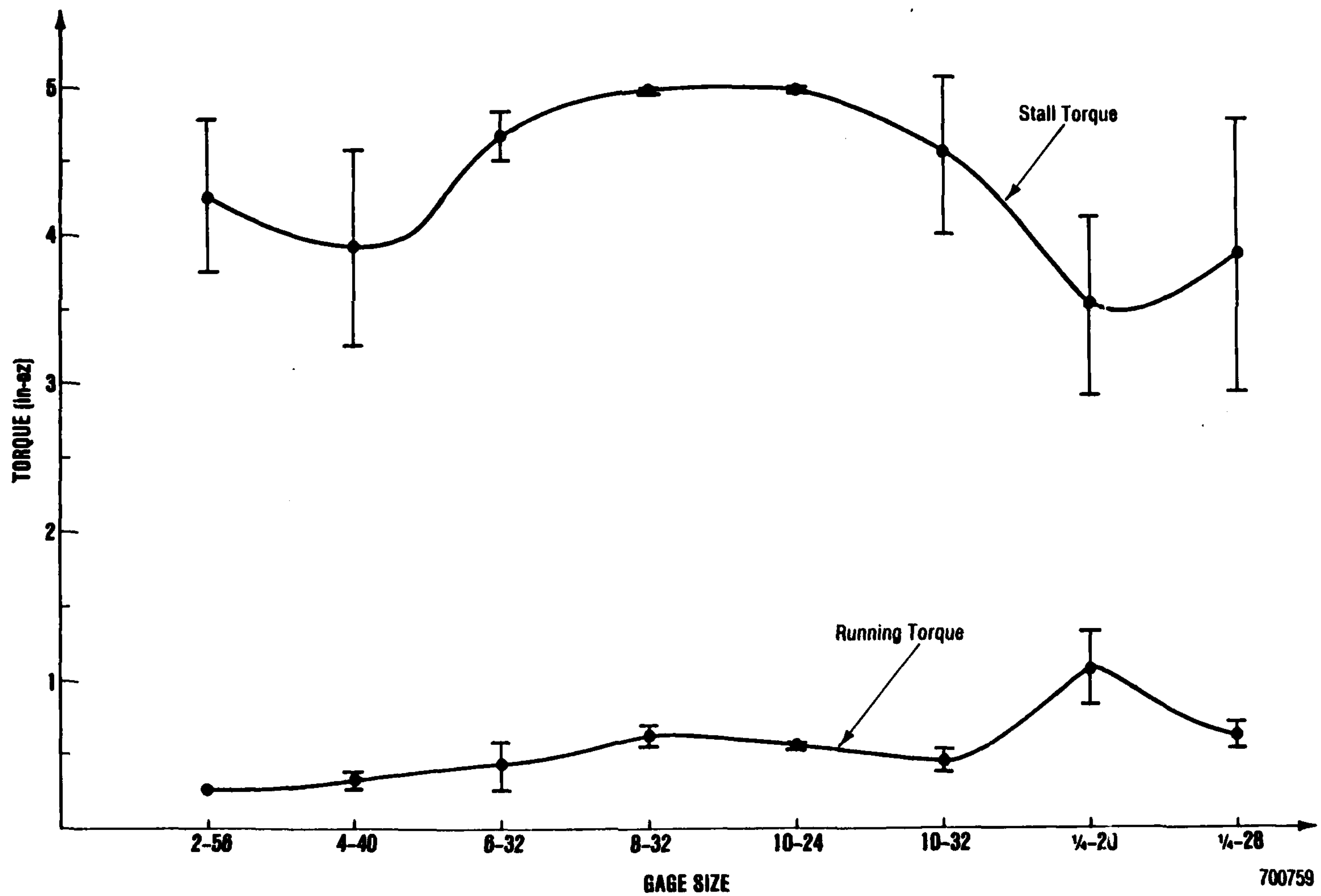


Figure 24

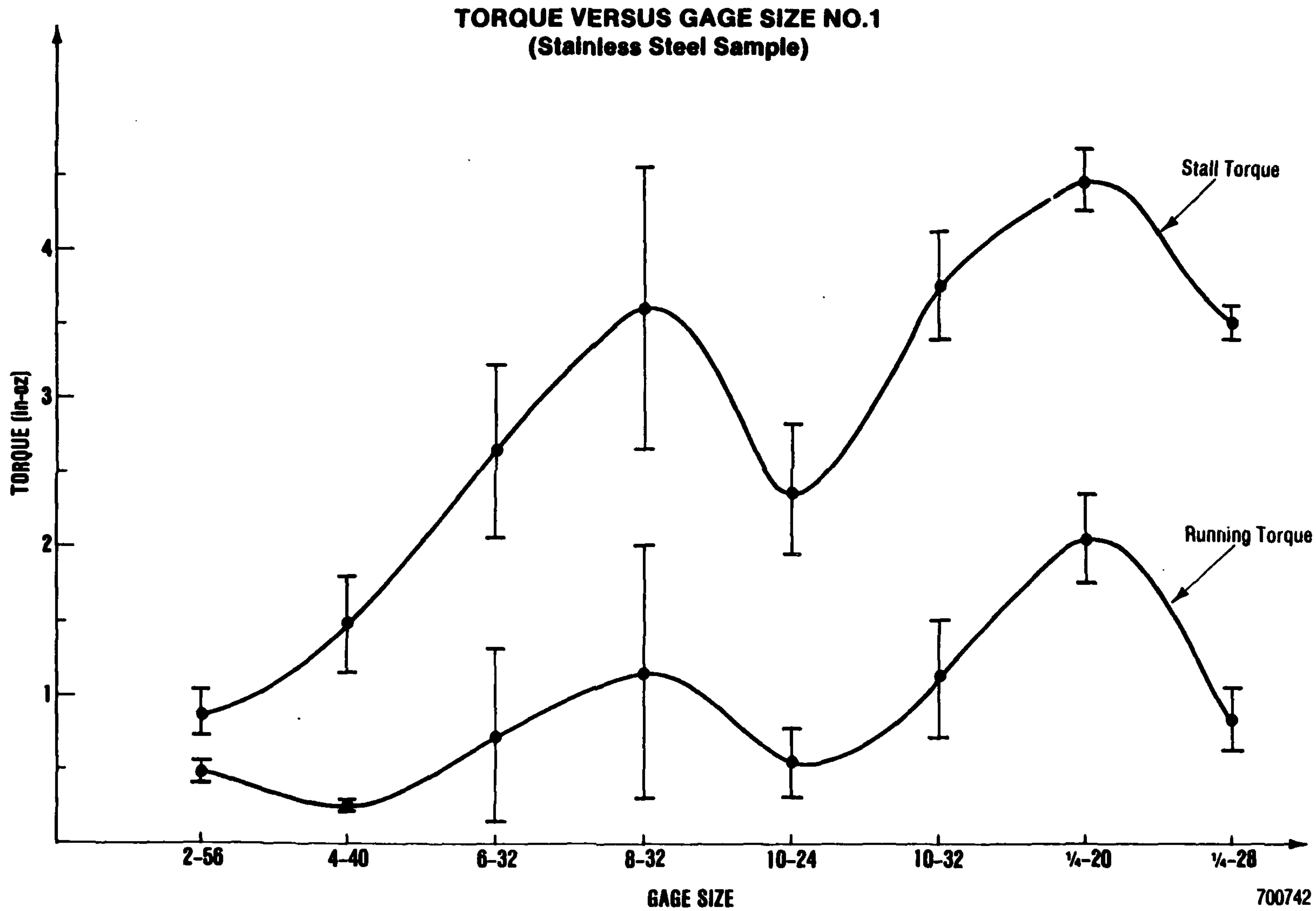

TORQUE VERSUS GAGE SIZE NO.1
(Stainless Steel Sample)
Stall Torque
Running Torque
TORQUE (in-oz)
1
2
3
4
2-56
4-40
6-32
8-32
10-24
10-32
¼-20
¼-28
GAGE SIZE
700742

Figure 25

TORQUE VERSUS GAGE SIZE NO.2
(Stainless Steel Sample)

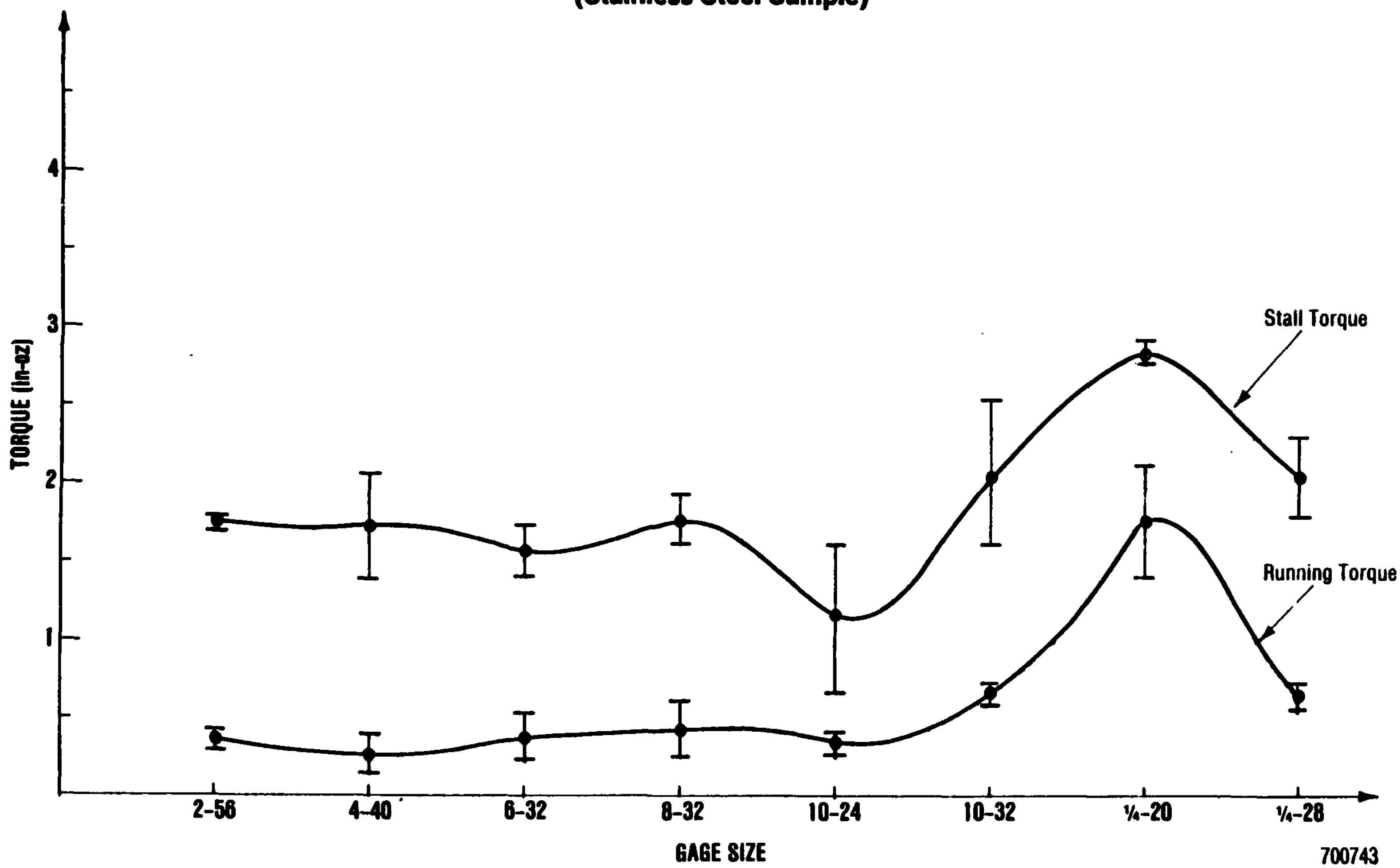


Figure 26

TORQUE VERSUS GAGE SIZE NO.3
(Stainless Steel Sample)

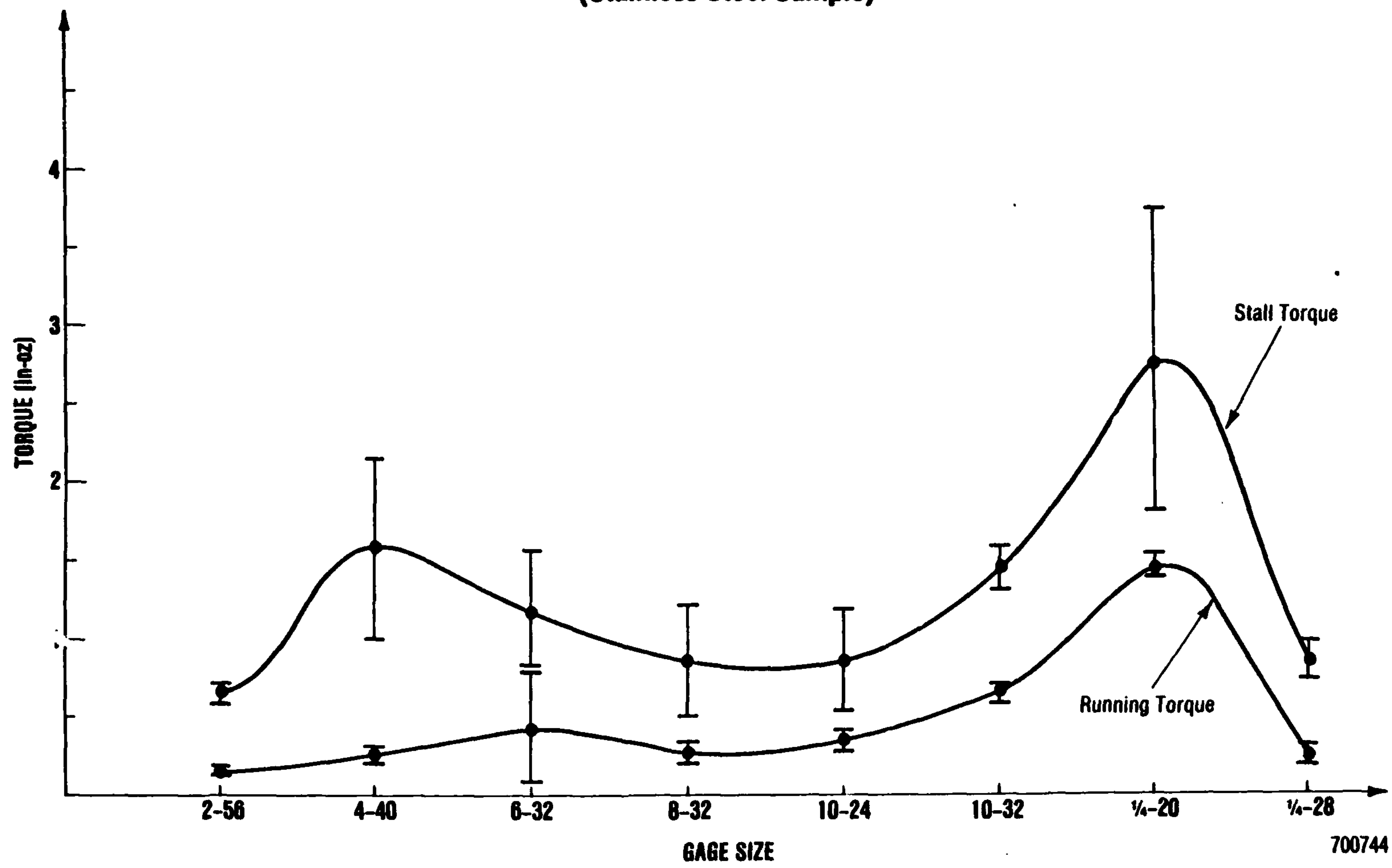


Figure 27

TORQUE VERSUS GAGE SIZE NO.4
(Stainless Steel Sample)

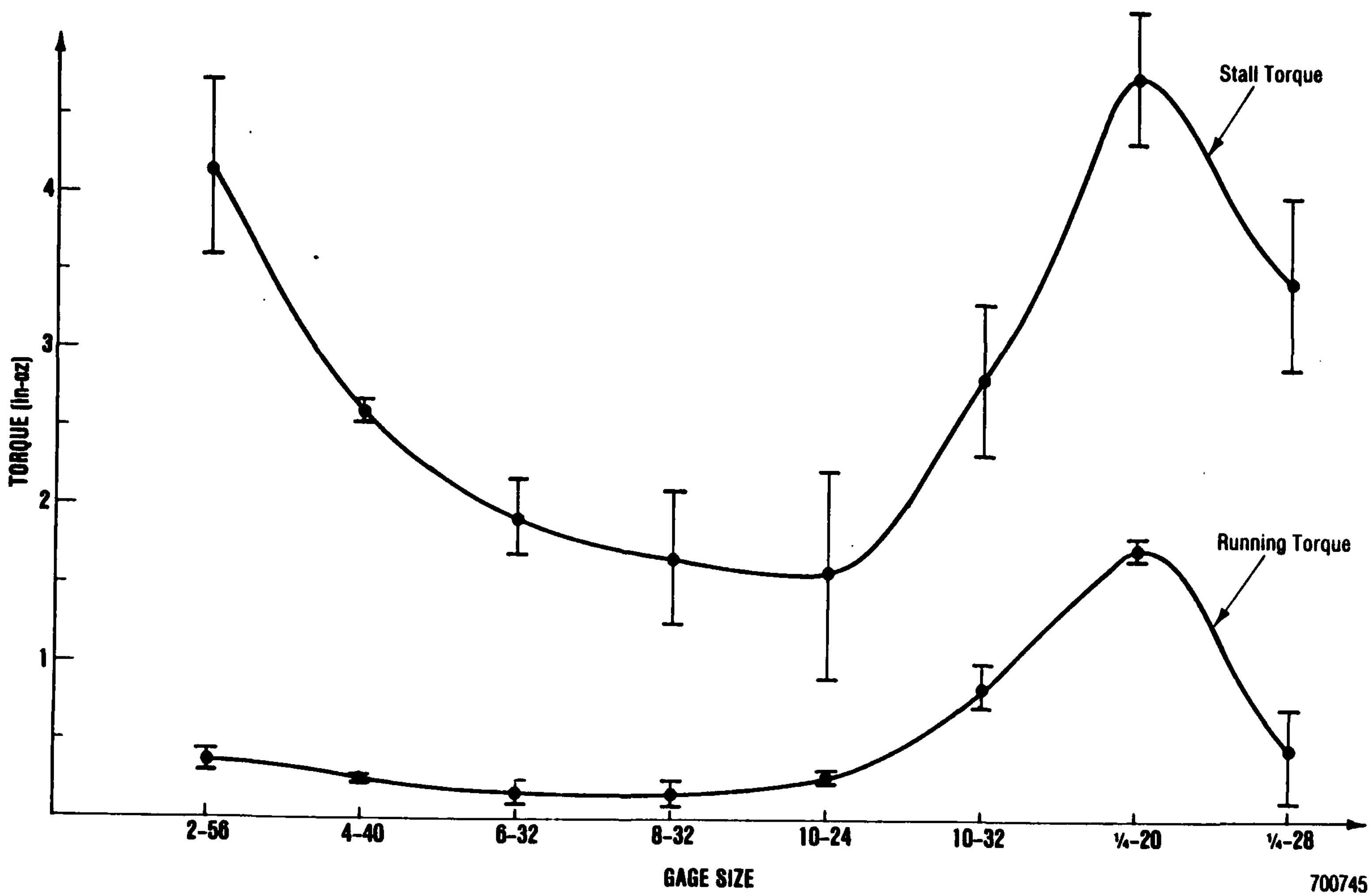


Figure 28

TORQUE VERSUS GAGE SIZE NO.5
(Stainless Steel Sample)

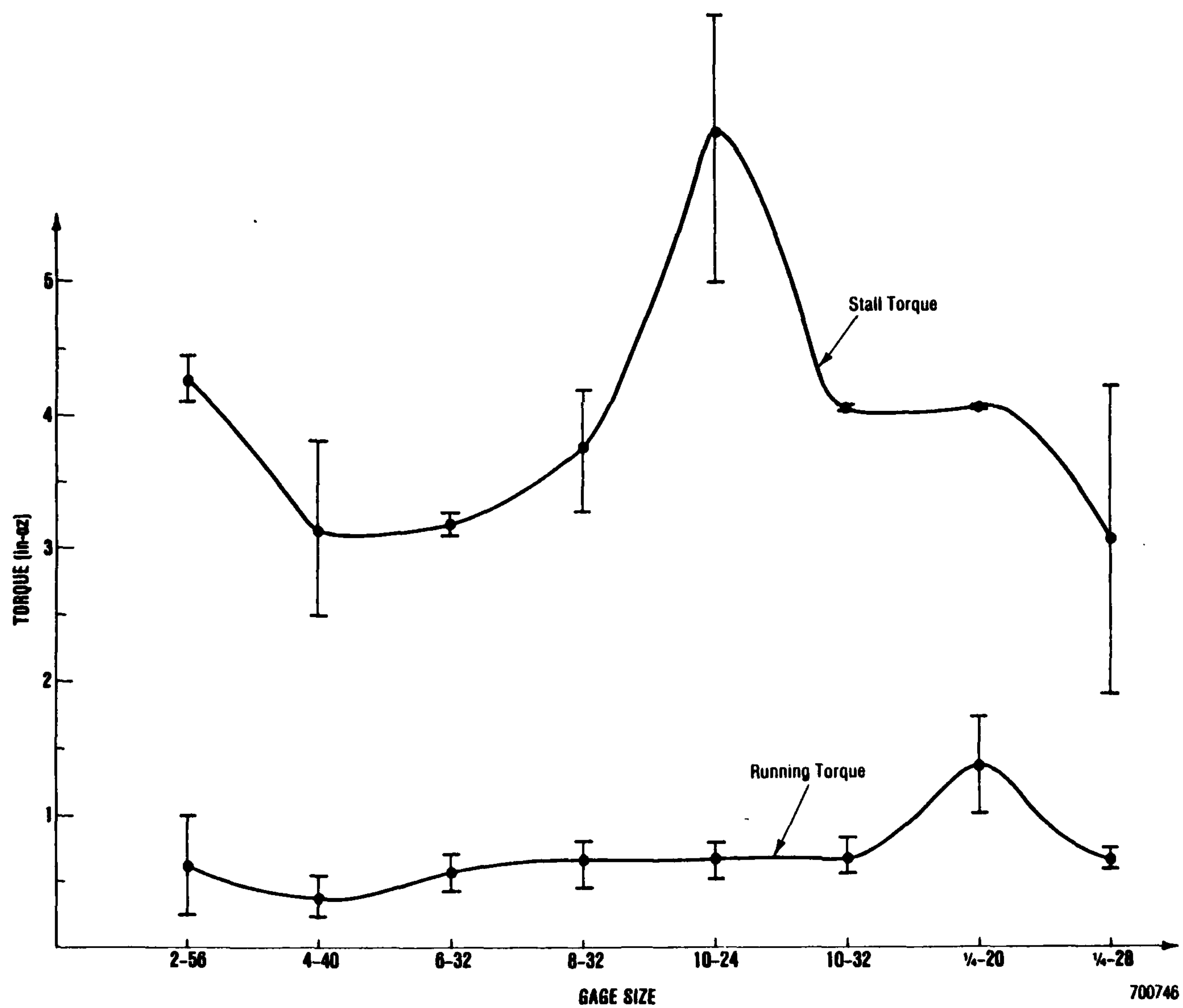


Figure 29

TORQUE VERSUS GAGE SIZE NO.6
(Stainless Steel Sample)

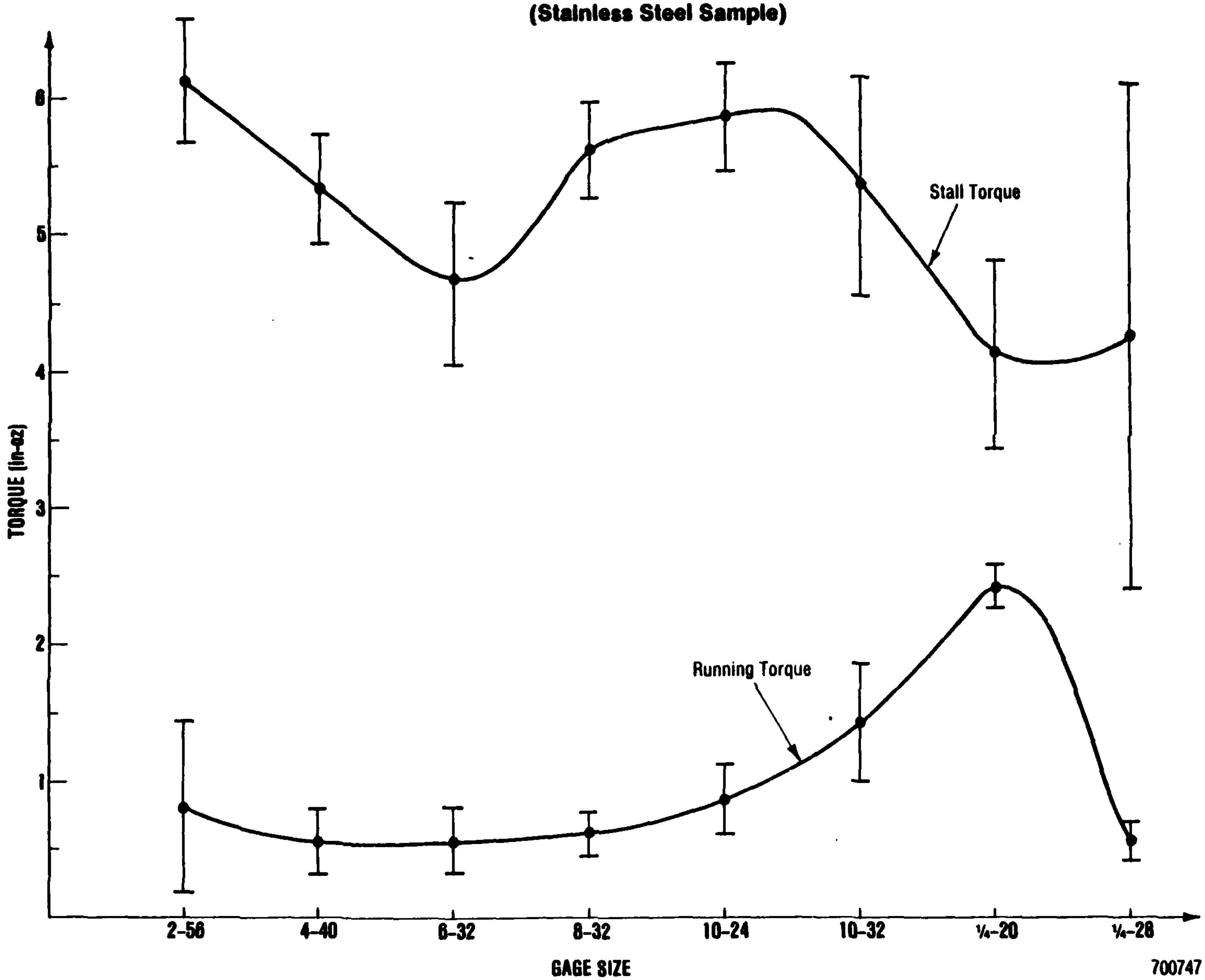


Figure 30

TORQUE VERSUS GAGE SIZE NO.7
(Stainless Steel Sample)

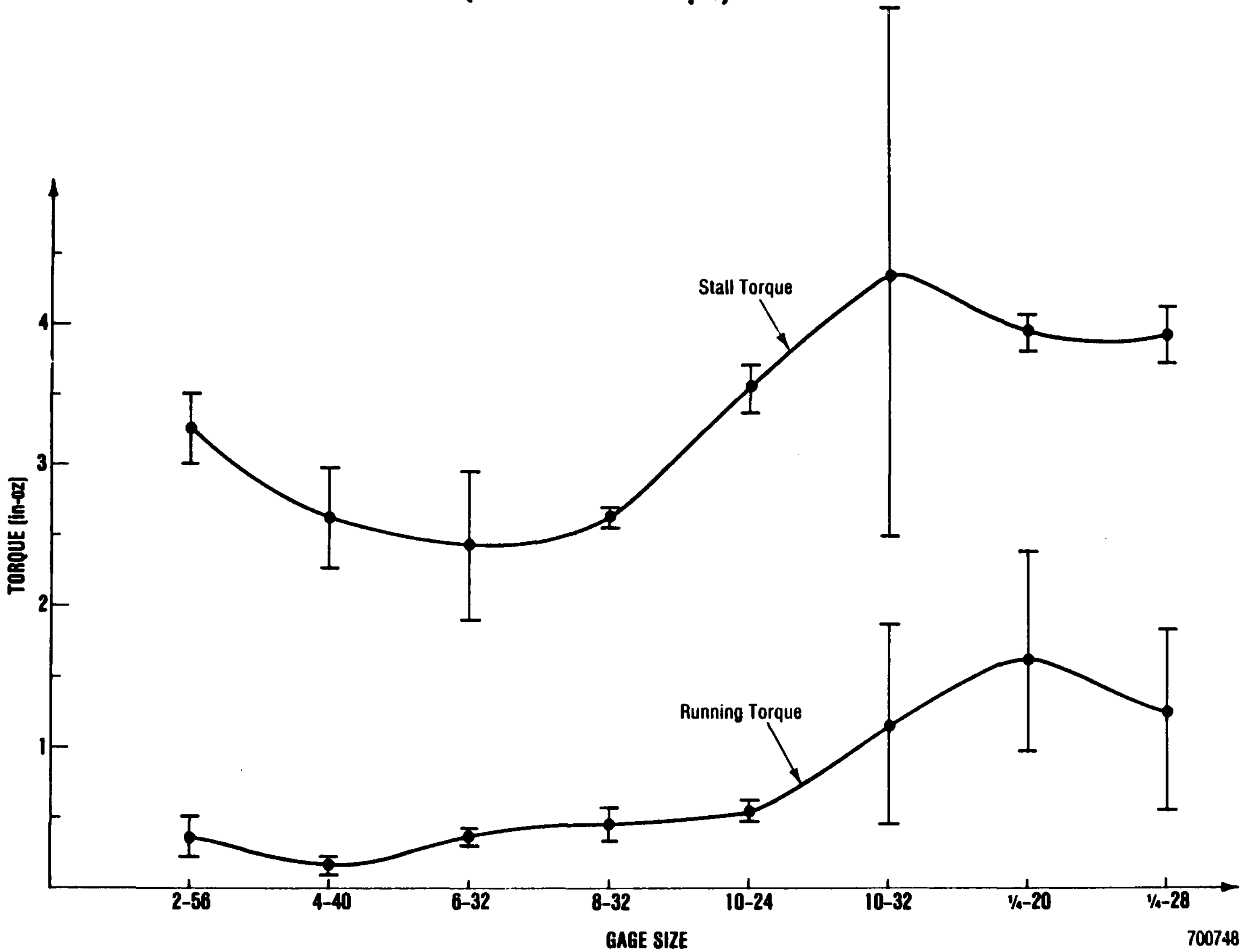


Figure 31

TORQUE VERSUS GAGE SIZE NO.8
(Stainless Steel Sample)

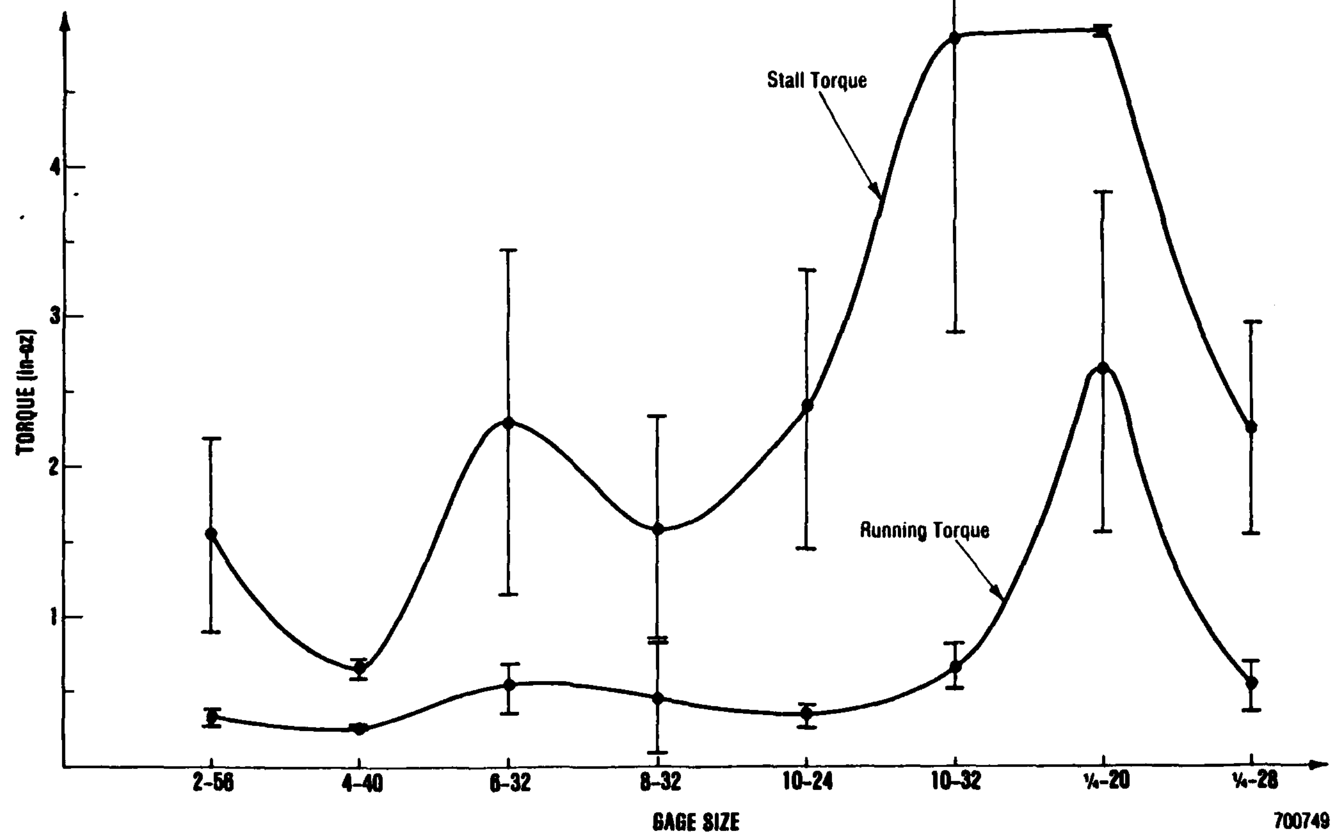


Figure 32

TORQUE VERSUS GAGE SIZE NO.9
(Stainless Steel Sample)

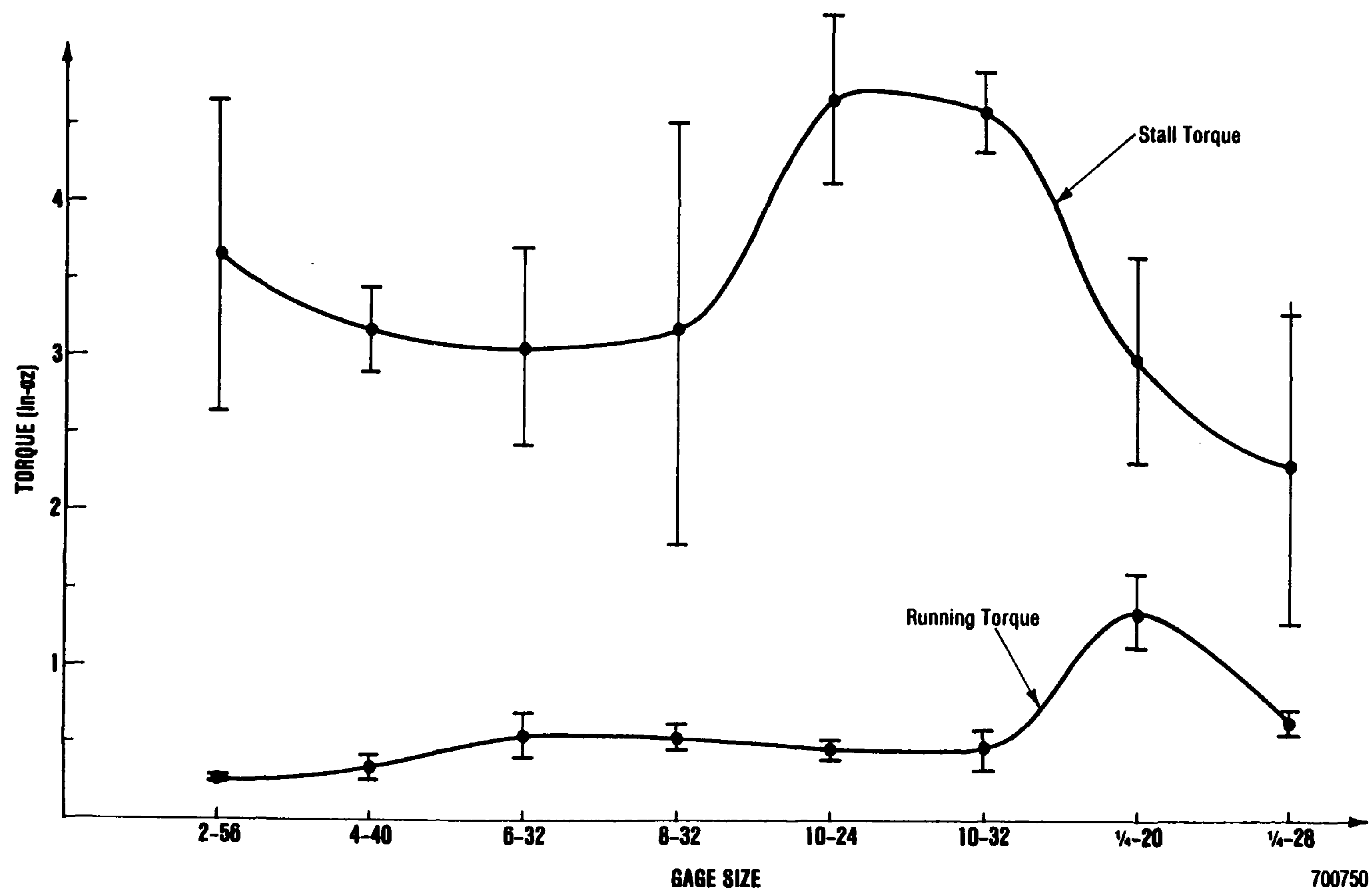


Figure 33

NORMALIZED DATA
TORQUE VERSUS GAGE SIZE
(Stainless Steel Sample)

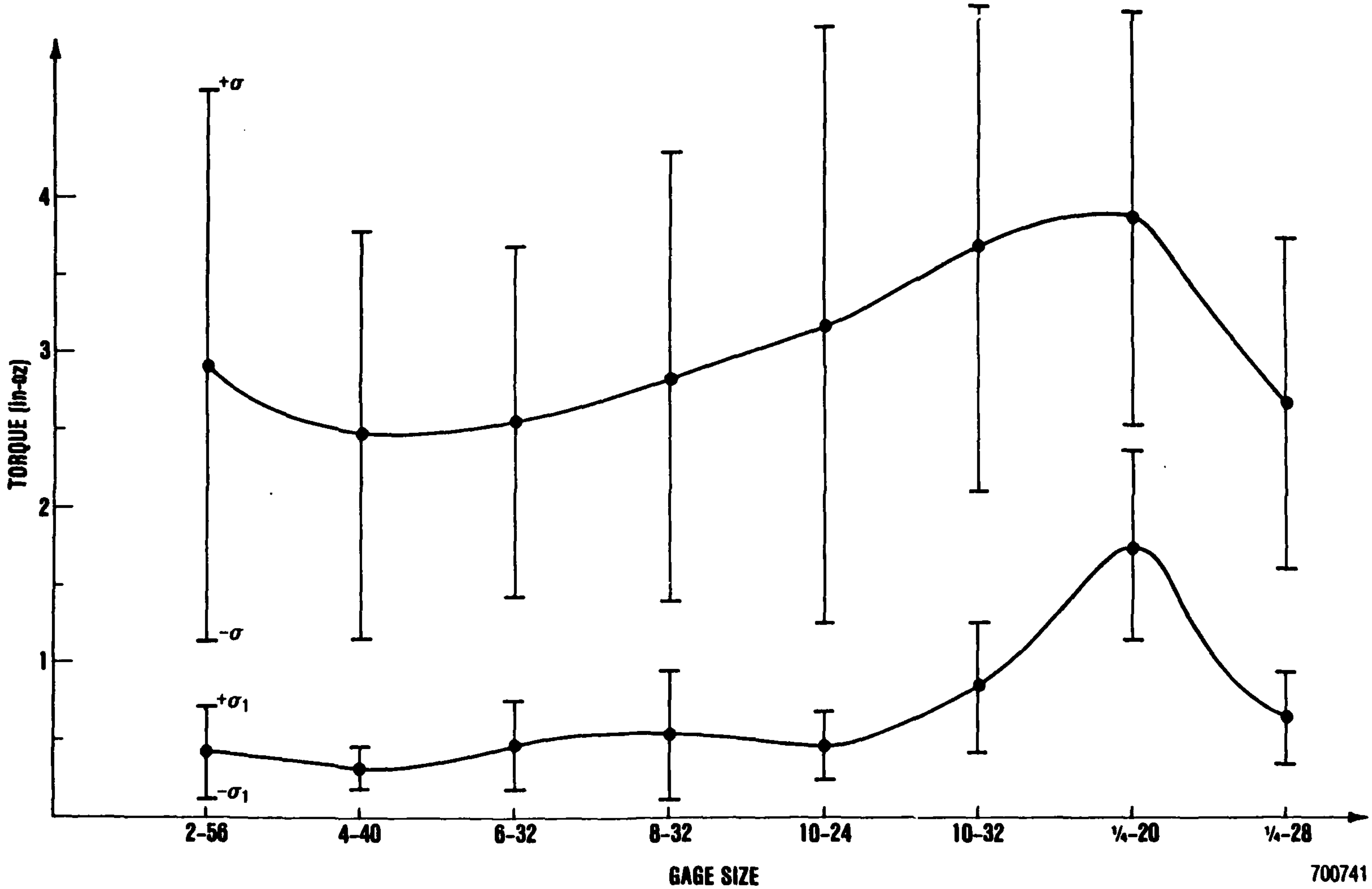


Figure 34

NORMALIZED DATA TORQUE VERSUS GAGE SIZE (Aluminum Sample)

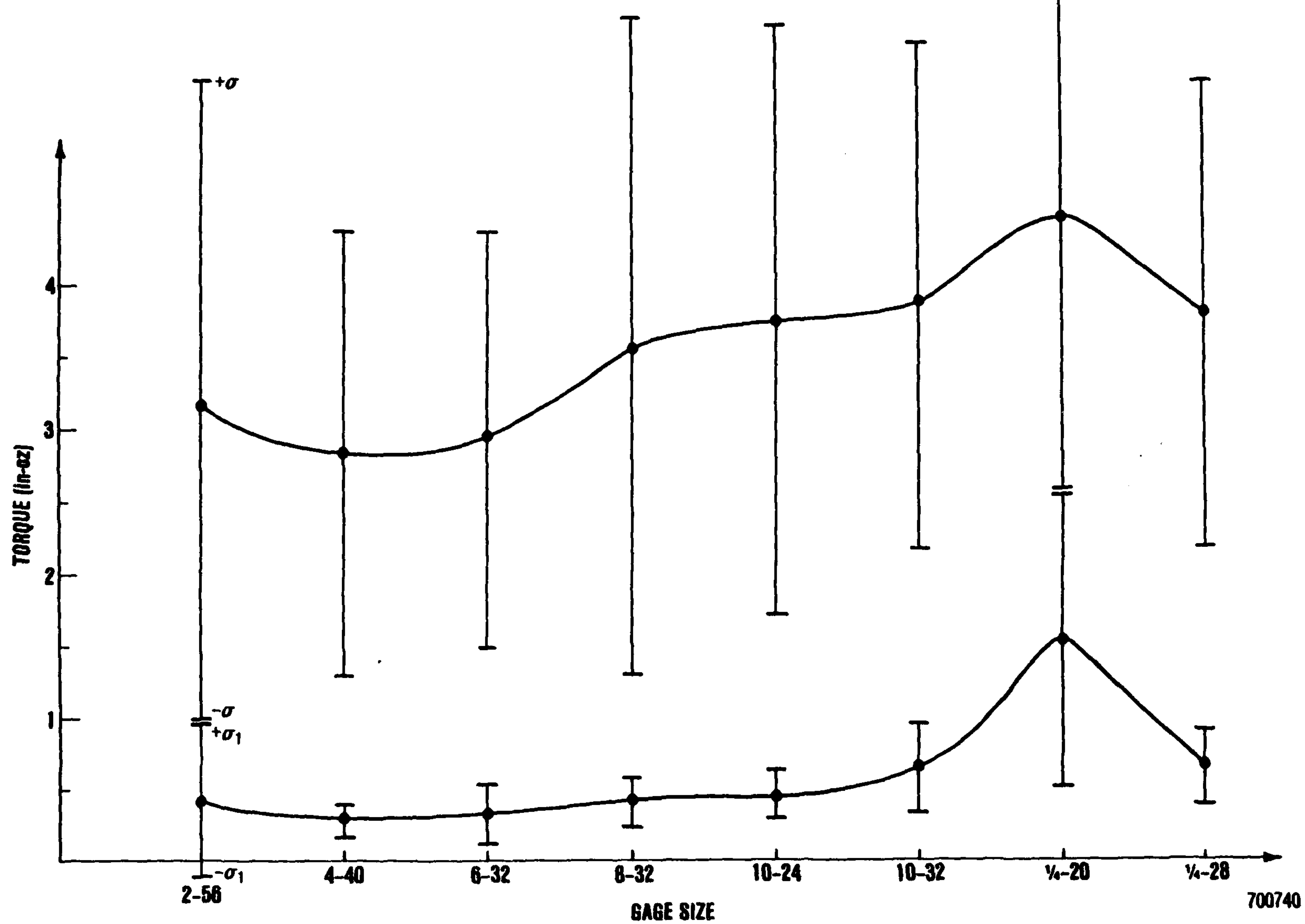


Figure 35

TORQUE THRESHOLD GUIDELINE

THREAD SIZE	TORQUE THRESHOLD
2	1.5 in-oz
4	2.0 in-oz
6	2.5 in-oz
8	3.0 in-oz
10	3.5 in-oz
¼	4.0 in-oz

700944

Figure 36

4TH ROTATIONAL AXIS WITH GRIPPER

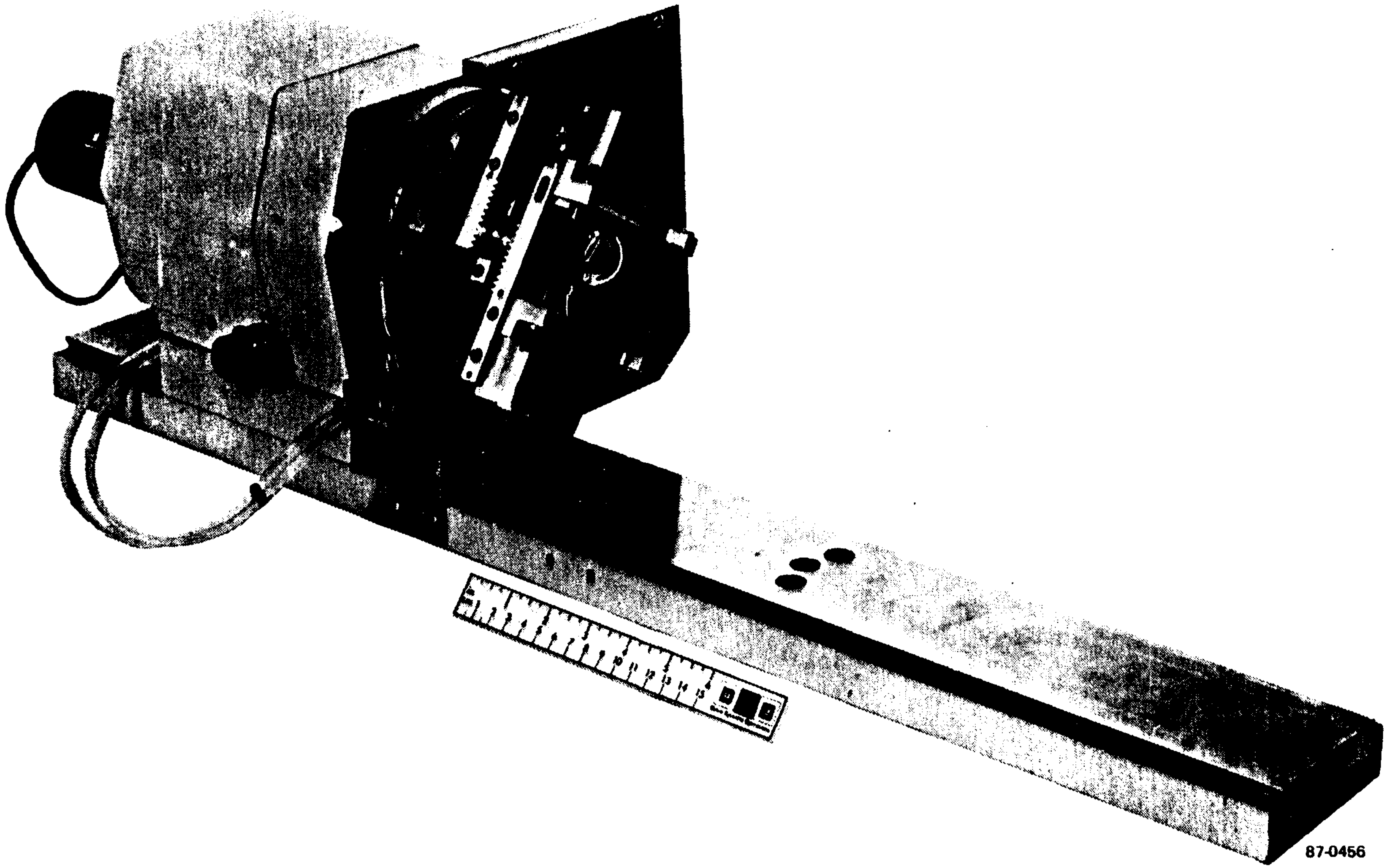


Figure 37

7.2.1 DESIGN

Three parts were chosen from Delco's F-16 Product Line as candidate sample parts for end effector development. (Bracket, 7561002; panel, 7565015; plate, 7566938; See Attached). These components were very representative of large volume hardware requiring thorough inspection at the time of selection. Figure 38 cross references gripper and part pallet designs necessary to accomodate the above sample parts. Figures 39 thru 41 illustrate pallet concepts.

In short, gripper designs were kept simple. A parallel jaw gripper (P/N FLAT-PG-284) for both robot and fourth axis were purchased from Mechanotron, Minneapolis, Mn. They were then modified with rack and pinion gearing (see drawing No. SK005340) to insure each gripper jaw acted synchronously. Gripper fingers were fully adjustable to accomodate various width parts by incorporating a sliding dovetail mount onto the gripper jaw. Range of motion was controlled by installing adjustable stops into the rack and pinion mechanism. Typical clearances between sample parts and gripper fingers, when open, ranged from .10 - .15 inches.

7.2.2 TESTING

During initial testing it was quickly found that all sample parts required accurate fixturing within their pallets in order to predictively place them into the fourth axis gripper system. Due to inaccuracies of robot motion this caused part/pallet binding as they were removed and collisions during pallet loading after inspection was complete.

To eliminate these effects parts were loaded loosely into their pallets. The robot gripper would then aquire a part and transport it to a staging area which consisted of nothing more than a granite surface plate. At the staging plate the robot would orient an edge of the part parallel to the staging plate within .005 inches, release, and then regrip it. Much like squaring off a deck of cards. The robot would then reorient the sample part to another known edge and again release and regrip. After repeating this cycle twice it was found that the robot could place the sample part within the fourth axis gripper with sufficient accuracy without requiring the use of search routines by the vision system. Based on this testing we attained the confidence level necessary to implement a material handling system for the View 1200 inspection process.

PRODUCT/GRIPPER/PALLET PART NO. CROSS REFERENCE

PRODUCT PART NO.	GRIPPER PART NO.	PALLET PART NO.
BRACKET 7561002	SK005390	SK005397
PANEL 7565015		SK005390
PLATE DG 100034		SK005396

700945

Figure 38

SAMPLE PART 1

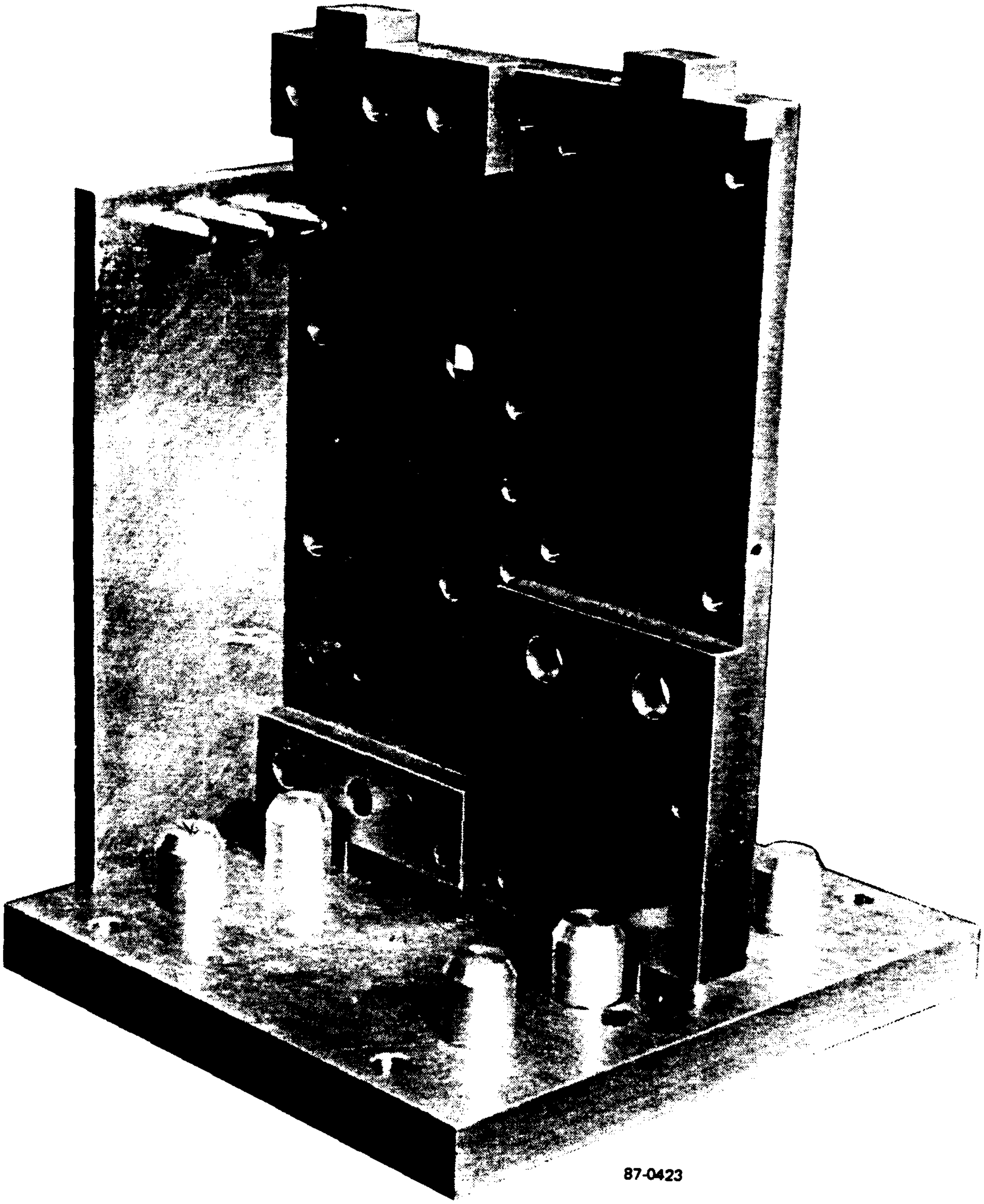


Figure 39

SAMPLE PART 2

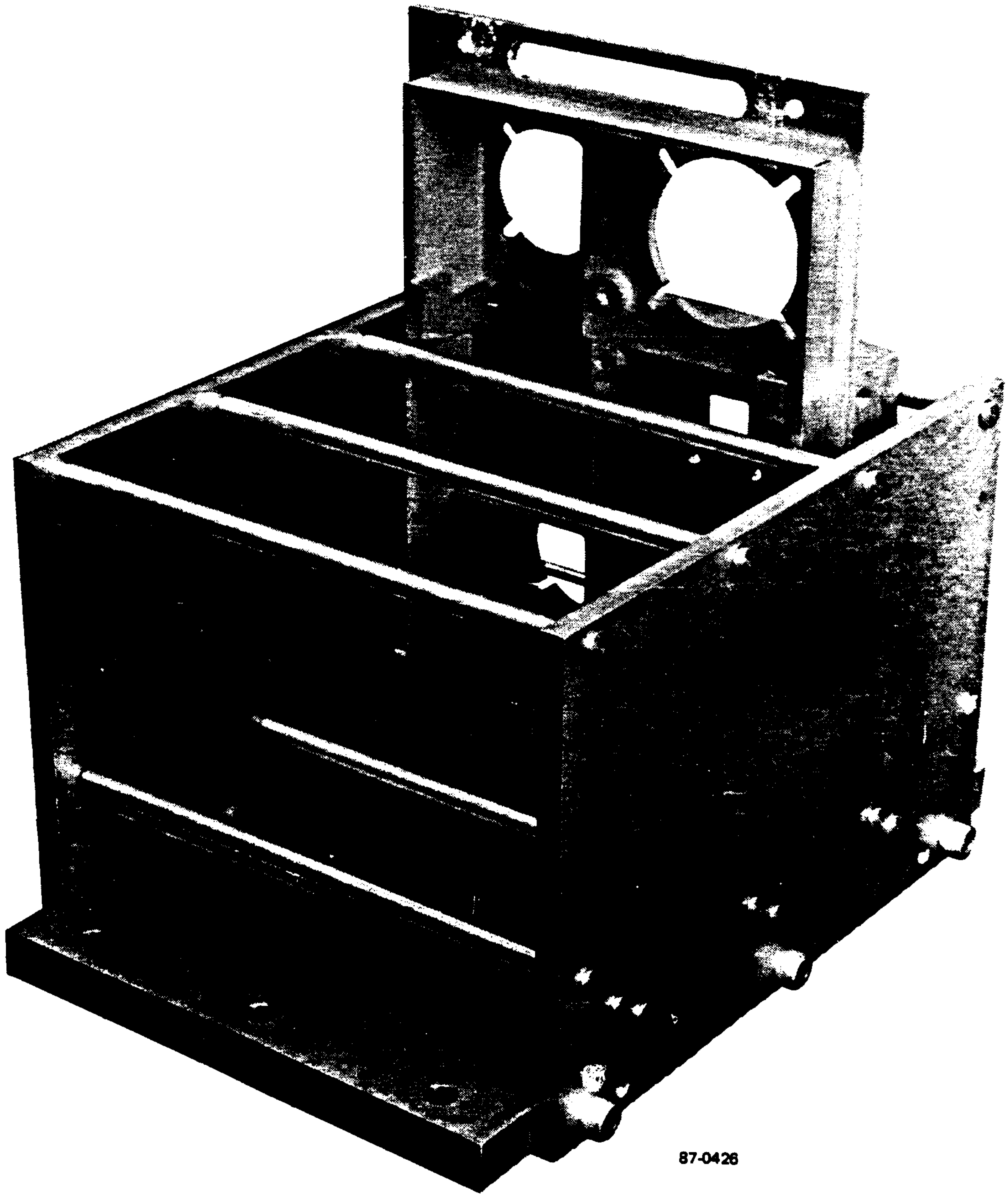


Figure 40

SAMPLE PART 3

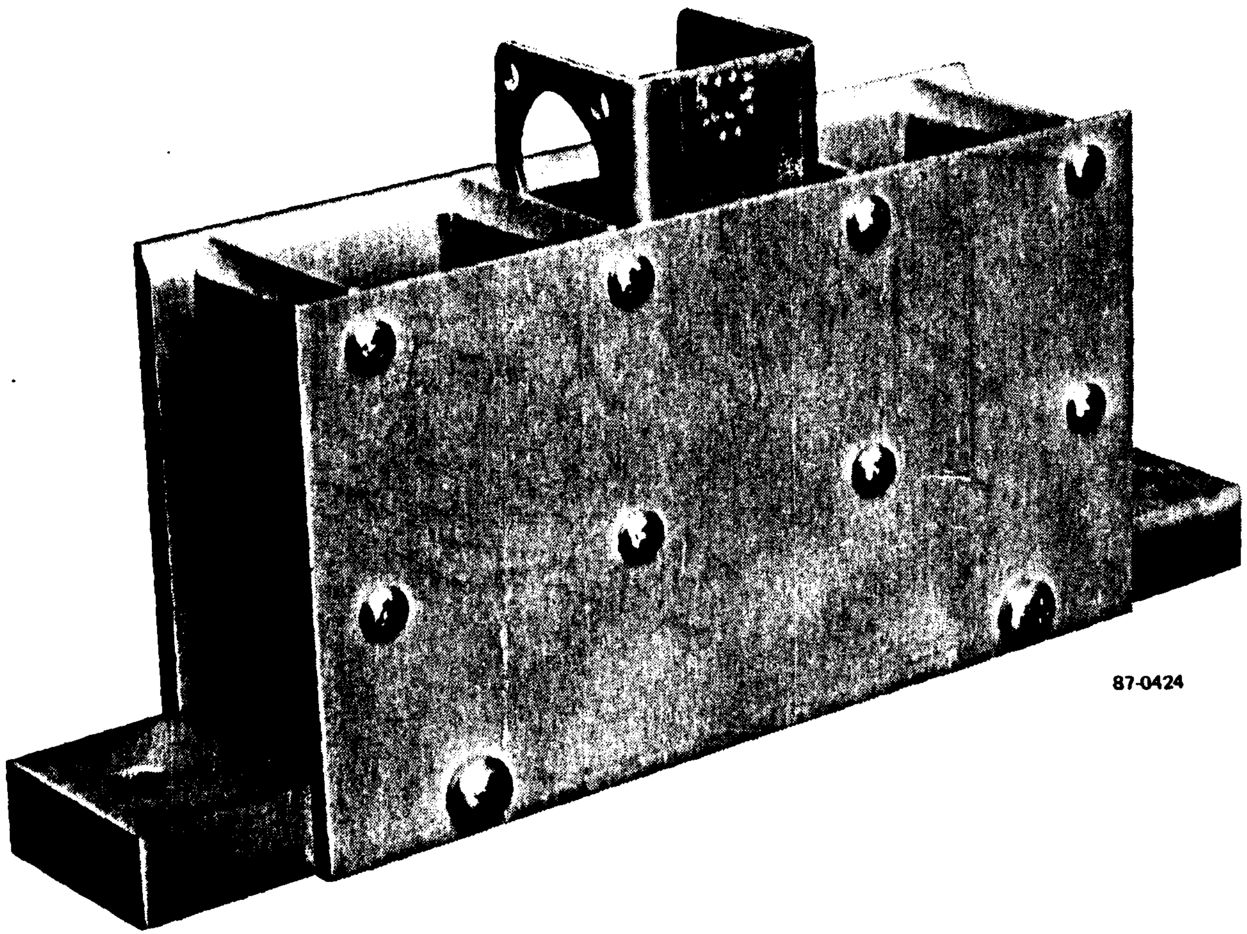


Figure 41

8.0 PROOF-OF-CONCEPT DESIGN

8.1 STATEMENT OF WORK DEFINITION

Based on the successful enabling technology development and testing it was determined that the automated mechanical inspection cell concept employing both dimensional and robotic thread inspection was technically feasible. The next step was to identify the specifications and standards required to construct a complete cell. Though the intent at this time was to develop only those subsystems that would represent a proof-of-concept design, it was felt that an overview of a total cell concept was necessary. Form the proof-of-concept cell additional subsystems and capabilities need only be added minimizing any potential redesign. Attached is a Statement of Work (E41-001) identifying the final cell design.

8.2 SYSTEM SUPERVISORY COMPUTER (SSC) CONTROL DESIGN

The primary function of the control program is to cause the execution of a series of View 1200 programs and Karel programs to take place in a specific sequence. The result of executing these programs is the inspection of the selected part (Attached is an example of A typical inspection report) according to the steps contained in these 'station programs'.

The names of programs to be executed at the stations are stored, in sequence of execution, in a file on disk. Through a series of menus (attached) presented on the system console, the operator makes selections which ultimately result in the use of the appropriate list of station programs. These programs are downloaded to and executed at the appropriate station, and results of the inspection process are uploaded to the SSC and stored on disk. When the end of a station program is sensed, the next program is processed in a similar fashion. This process continues until the list of station programs is exhausted. At this point, the specified inspection is complete and the operator is once again presented with the initial menu which began the process just described.

The station programs to be executed can reside on either mountable flexible disk, or permanently mounted Winchester disk. The operator specifies their location as part of the menu oriented dialog prior to part inspection.

The operator is kept abreast of inspection progress through a series of informational and explanatory messages. In certain cases, when an operator selection error has been detected by the control program, such messages are followed by repetition of the menu selection or prompt requiring correction.

8.2.1 EXCHANGING MESSAGES WITH THE VIEW 1200

Station programs and inspection results are transferred between the View 1200 and SSC through control program implementation of a message exchange protocol compatible with the protocol supplied as part of the View 1200. Capabilities include transfer of station programs in both directions, receipt of inspection results at the SSC and transmission of control commands to the View 1200.

8.2.2 EXCHANGING MESSAGES WITH THE KAREL CONTROLLER

Station programs and inspection results are transferred between the Karel and the SSC through the use of Digital Data Communications Message Protocol (DDCMP) and Manufacturing Message Format Specification (MMFS). DDCMP is widely used, and was developed by Digital Equipment Corporation. MMFS is part of the Manufacturing Automation Protocol (MAP) originated by General Motors. The Karel provides a subset of the full MMFS; it and the portion implemented for use on the SSC provide sufficient capability for transfer of station programs, transmission of inspection results and SSC control of the Karel.

8.3 THREAD INSPECTION EOAT DESIGN

The thread Inspection End-of-Arm-Tooling is comprised of: 1) a Motorized Drive System with positional encoding, 2) a gage holding mechanism with built in compliance, 3) Control Electronics, and 4) Control Software. The system was designed to operate on command from a GMF Karel Controller, however, is fully adaptable to any other robotic controller provided it has discrete and RS232 with read/write I/O capability.

8.3.1 MECHANICAL HARDWARE

The mechanical end-of-arm-tooling consists of two basic units (see Figure 42). The upper drive section contains a 20 inch-oz DC Servomotor, 1000 count encoder, and 40 conductor slip ring. The encoder is used for speed control and positional feedback to a motor controller while the slip ring supplies power and sensor access to the rotating tool section. The lower tool section consists of a telescoping gage tip, bellows joint for lateral compliance, 12 VDC Solenoid drive to extend the tool tip, and a home sensor.

When the gage is positioned over the tapped hole the solenoid drive extends the gage off it's seat and mildly preloads it against the tapped hole opening. This action also allows the gage to improve its oientation laterially over the tapped hole due to the bellows linkage above. As the gage is drawn into the hole, solenoid power is no longer required and it is de-energized. When the programmed threshold torque, specific to the thread size, is attained rotational motion is stopped. A counter within the motor controller is zeroed and counter-rotation, to extract the gage, is started. As the gage is extracted the robot moves in a positive direction .25 inches at the same exit feed-rate as the gage. This allows the gage to snap out of the tapped hole into its home position. When the sensor output is detected motor motion is stopped and a total exit revolution count can be determined. Knowing the thread pitch, the depth of the tapped hole can be calculated.

By trial and error it was determined that the robot could position the gage over the hole within ± .015 inches without any noticeable effects on torque thresholding. This allows usage of this EOAT on just about any robot without effecting its performance and allowed us to delete the requirement of closing a force loop with the robot in X and Y directions to guarantee gage-to-threaded hole alignment.

During the initial testing phase we asssumed that threshold torque measurements would have to be monitored by the force/moment sensor. However, it soon became apparent that due to mechanical noise contributed by the robot that the sensor could not resolve the required torques. Attempts were made to mount the sensor in the rotating frame as well as the stationary frame to no avail. It was then determined that by scaling motor current, threshold torques could be measured at their desired resolution. The system by which this was achieved will be discussed in greater detail in the following section.

8.3.2 CONTROL ELECTRONICS/SOFTWARE (KAREL)

The controlling elements of the thread inspection EOAT include a motor controller, digital torque detection electronics, and the Karel Controller.

Operationally the system has two modes: Calibration and Running. During the Running Mode Programming specific to hardware requiring inspection positions the EOAT over the first threaded hole to be gaged. At this time a standardized subroutine (Attached) is recalled from memory and commands are downloaded via RS232 and discrete I/O from the Karel Controller to the Motor Controller and Torque Detection Electronics, respectively.

The Motor Controller requires information defining direction of rotation and maximum number of entry revolutions. The Torque Detection Electronics receives an 8-bit discrete signal defining the threshold at which gage rotation stops. After setup information is received a 'start' command is sent to motor controller. When the Torque Threshold, specific to thread size, is attained a discrete signal is returned to the Karel whereupon it transmits a "stop motion" command to the Motor Controller. At this time, the rotational counter register in the Motor Controller is also set to zero. This allows exit revolutions to be counted during extraction. When the gage exits the tapped hole the home sensor within the EOAT acts similarily to the thresholding circuit. It notifies the Karel Controller that a "stop motion" command needs to be transmitted to the Motor Controller.

As indicated earlier, torque is determined by scaling motor current. To account for motor current required to drive the EOAT (without thread engagement) a calibration mode was added. During system initialization at power up, software (attached) at the Karel commands the motor to rotate ten revolutions. During this time current is monitored, averaged, digitized and stored into memory located on the torque detection electronics board. During the remainder of the "work shift" this value is added to the desired torque threshold downloaded from the karel thereby compensating the system for inherent frictional effects.

Also, during calibration user specific parameters required by the motor controller are set. For our application these included motor speed, acceleration, pole and zero locations (contol feedback parameters) and operational mode(velocity, position or torque). This application required the motor to work in a velocity mode. Reference figures 43 A,B,C for a block diagram representation of the above described process.

8.4 LABORATORY LAYOUT

The laboratory layout used during the Proof-of-Concept phase is shown in Figure 44. Robot location was chosen to facilitate material handling concept tests with the View 1200.

EOAT CROSS SECTION VIEW

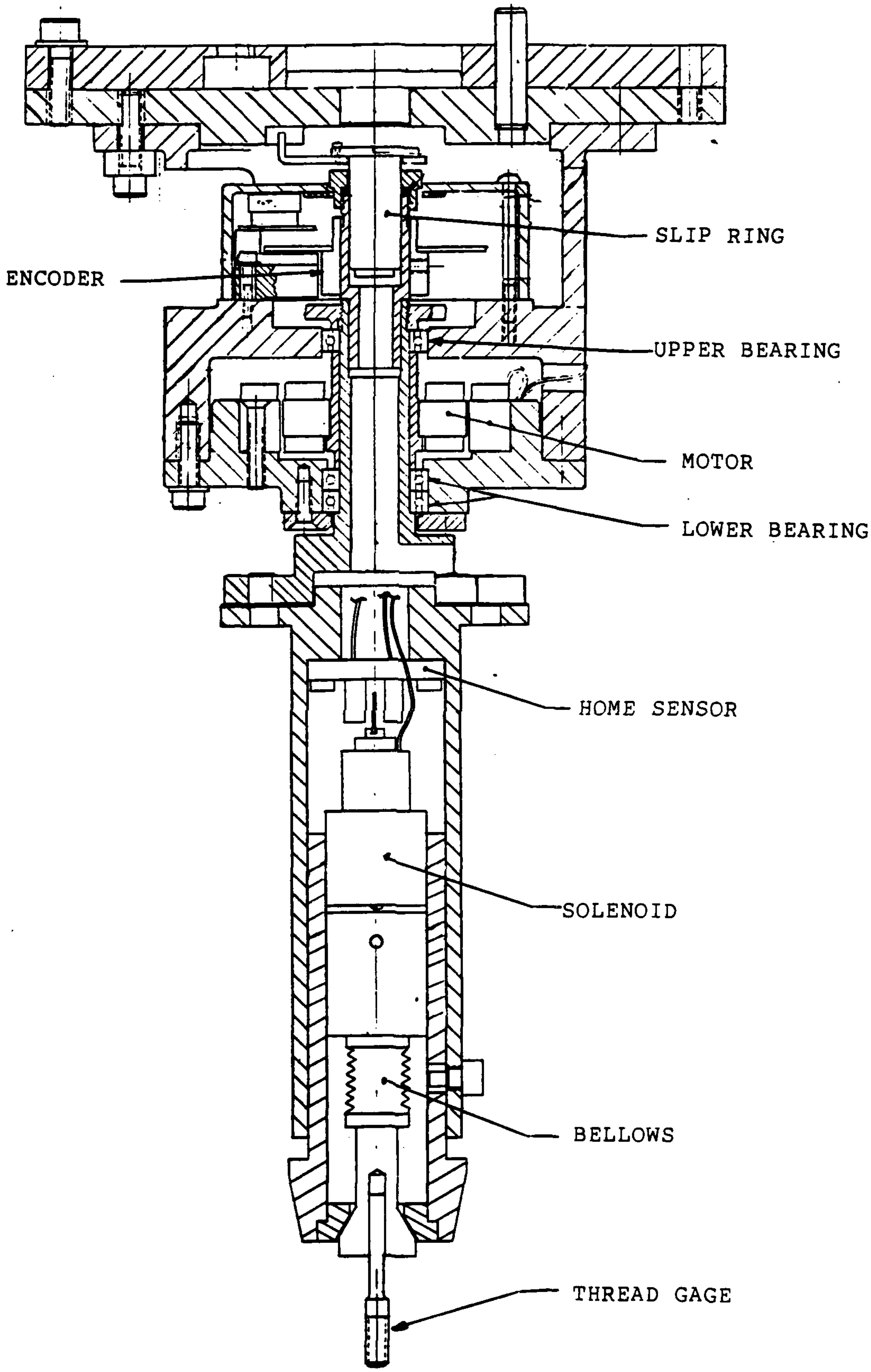


Figure 42

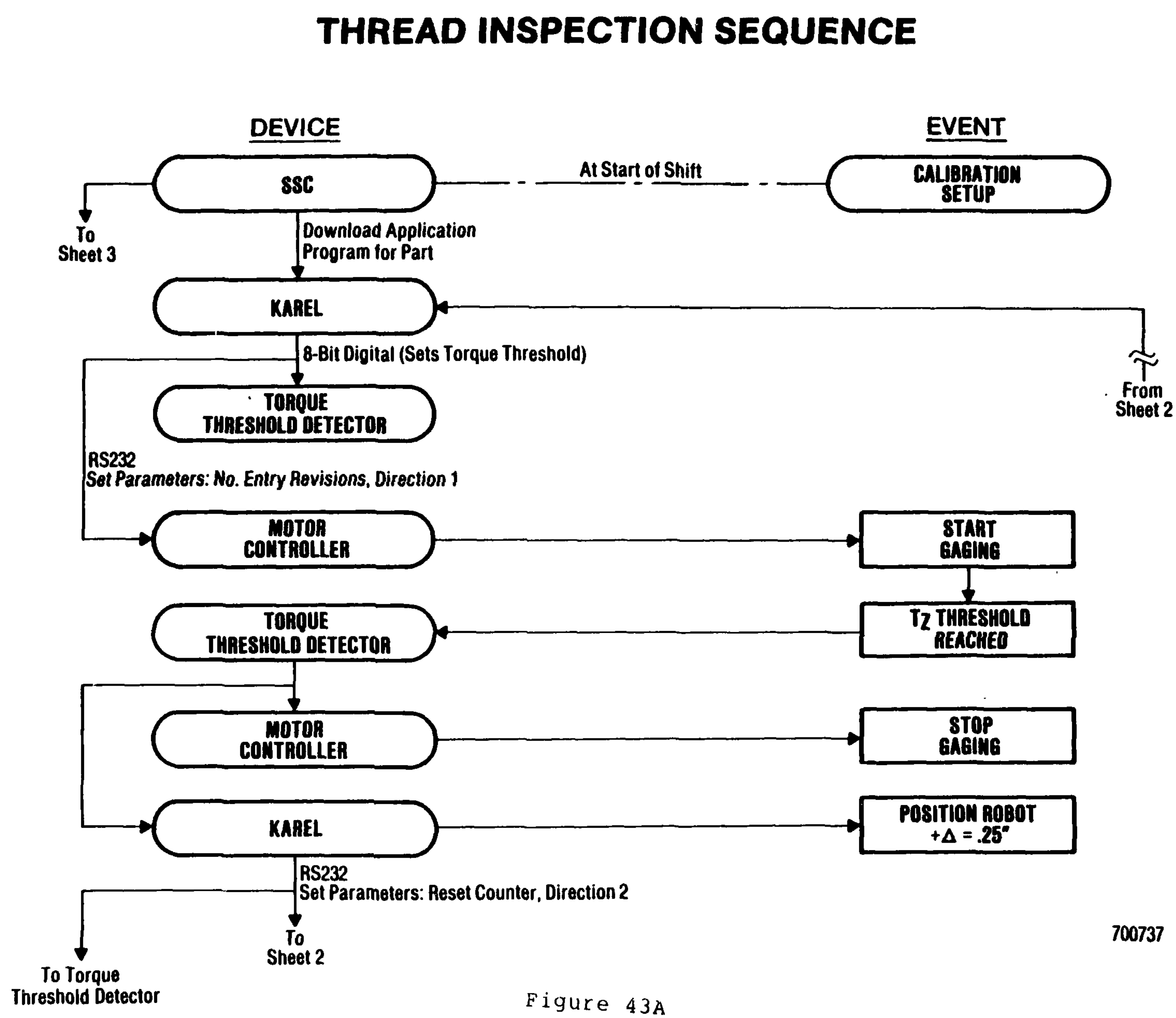

THREAD INSPECTION SEQUENCE
DEVICE
EVENT
SSC
At Start of Shift
CALIBRATION SETUP
To Sheet 3
Download Application Program for Part
KAREL
From Sheet 2
8-Bit Digital (Sets Torque Threshold)
TORQUE THRESHOLD DETECTOR
RS232
Set Parameters: No. Entry Revisions, Direction 1
MOTOR CONTROLLER
START GAGING
TORQUE THRESHOLD DETECTOR
Tz THRESHOLD REACHED
MOTOR CONTROLLER
STOP GAGING
KAREL
POSITION ROBOT +Δ = .25"
RS232
Set Parameters: Reset Counter, Direction 2
To Sheet 2
To Torque Threshold Detector
700737

Figure 43A

THREAD INSPECTION SEQUENCE (Con't)

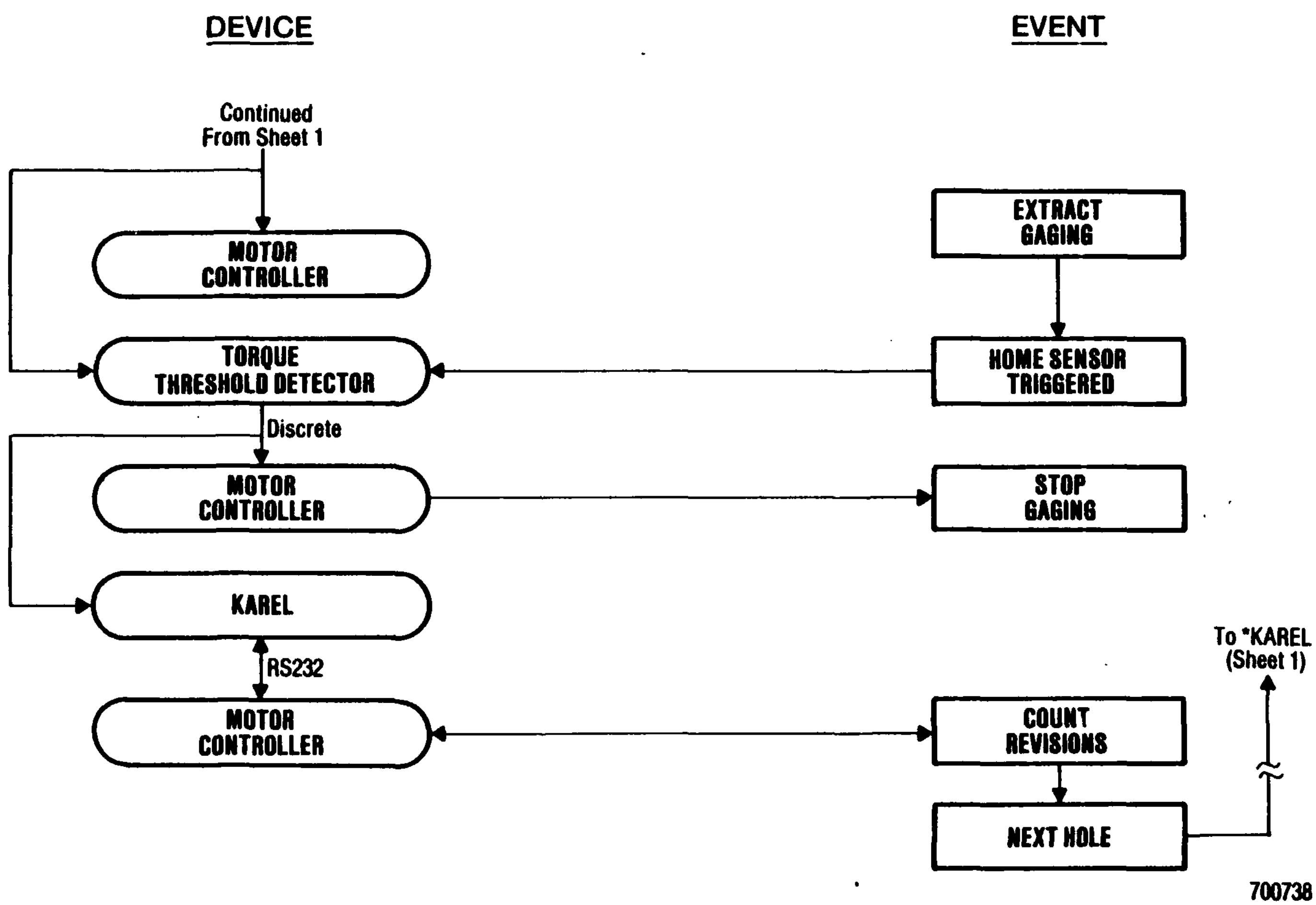


Figure 43B

CALIBRATION SEQUENCE (Cont'd)

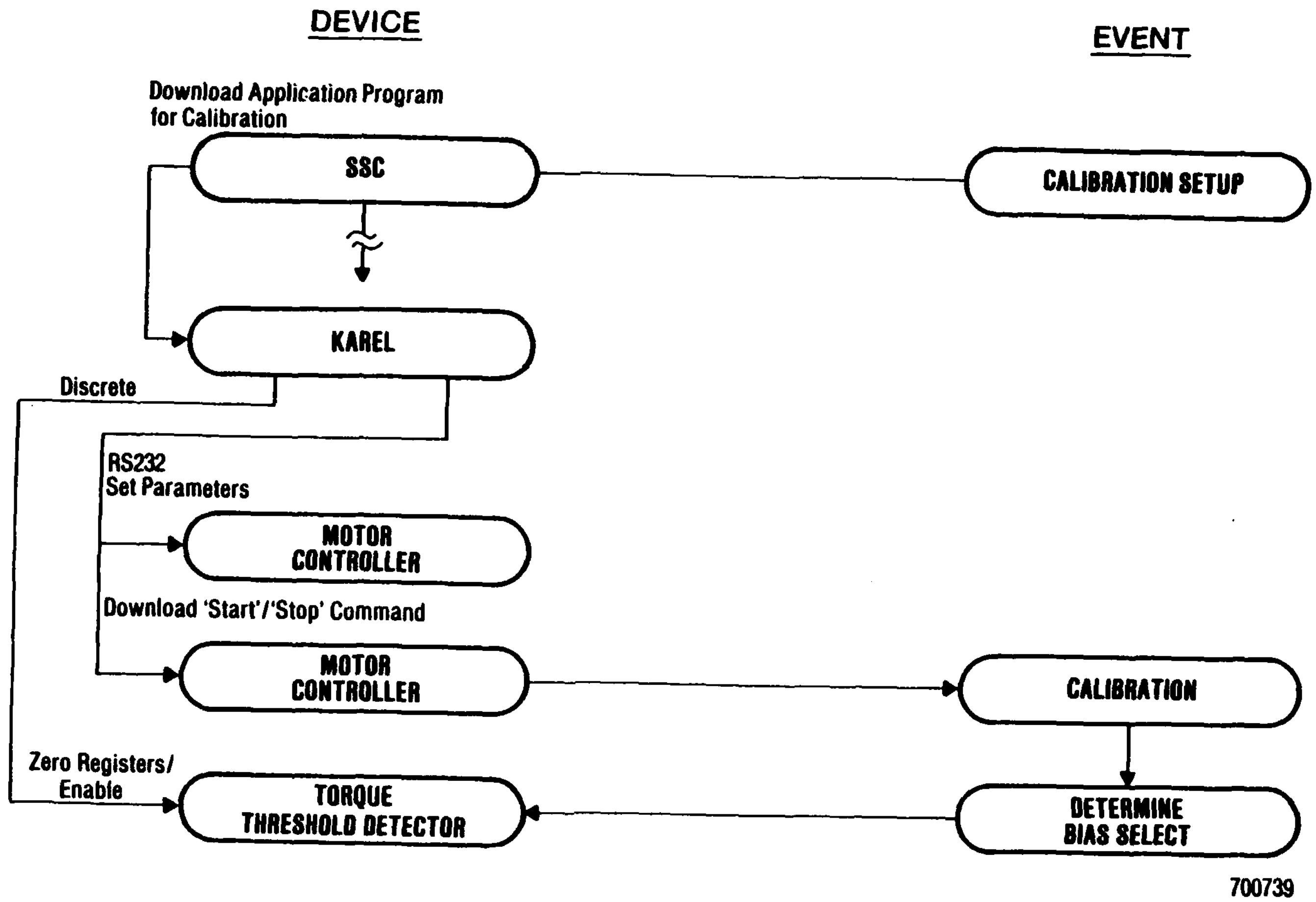


Figure 43C

LABORATORY LAYOUT

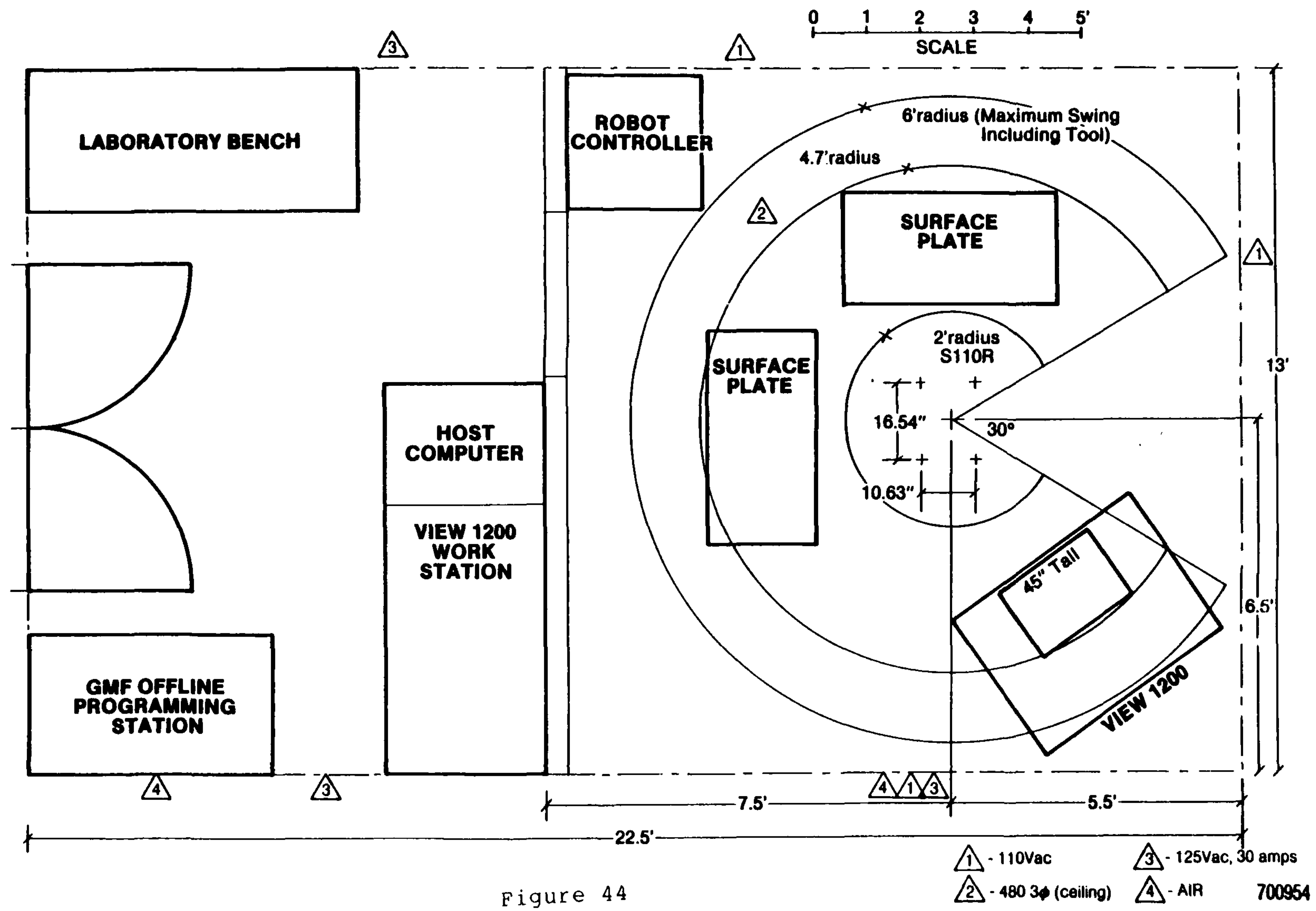


Figure 44

9.0 AREAS FOR FUTURE CONCERN/DEVELOPMENT

To complete the thread inspection system, gaging quick-change concepts in addition to drive system redesigns need to be addressed. Presently, Go and No Go Gaging is mechanically fastened to the end-of-arm-tooling. Conversion to a quick change tooling concept requires an electro-magnetic quick design to replace the existing tool holder. Regarding drive system redesign, the existing assembly utilized design configurations originally intended to meet a broad range of test requirements or performance standards. Selection of the 40 conductor slip ring was based on unknown electronics that potentially may have been placed in the rotating frame. A redesigned assembly would need no more than 7 conductors (3 for home sensor, 2 for solenoid and 2 for proposed electromagnetics). The designed bearing configuration utilizes a duplexed bearing set in the lower housing section and a single bearing in the upper. Again, due to unknown payloads at the time of design an overly rigid structure was concepted. Redesign would eliminate one bearing from the lower section and reconfigure the bearing style to a spaced duplex set.

The benefits of the drive system redesign would decrease the free running torque. This torque is approximately .7 - .9 in-oz. and is presently compensated for during the claibration mode. Depending of the final design and subsequent testing it may be possible to eliminate the calibration mode all together.

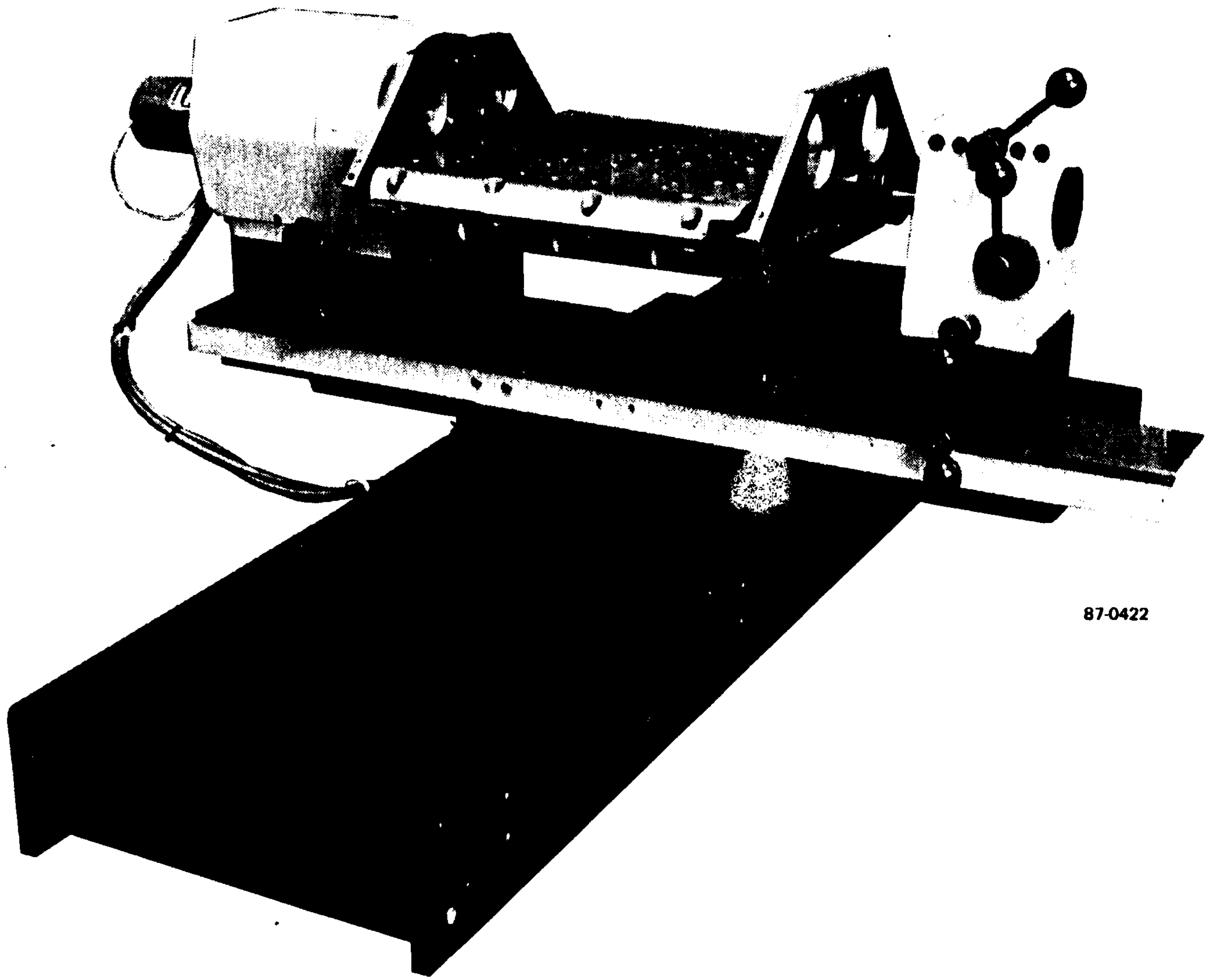
10.0 FINAL DESIGN

At approximately halfway through the proof-of-concept development effort it became apparent that thread inspection would not be utilized in a production capacity as initially expected. Programs involving large volumes of "bare" tapped holes have been completed and anticipated programs did not materialize. The bulk of Delco's future programs involving mechanical assemblies have been outsourced and rely heavily on source inspection. Also, those assemblies that will be fabricaed in house utilize locking inserts for which this inspection cell was not designed. For these reasons the study effort regarding thread inspection was completed, however final designs to implement this system on a production basis were not pursued. The original intended user of the inspection cell was the Delco Milwaukee Manufacturing Group. However, due to product and inspection outsourcing the installation location has changed to Delco Systems in Goleta.

The final system configuration also reverted to the stand alone View 1200 without material handling and thread inspection. The View 1200 Fourth Rotational Axis was modified to include a tooling plate onto which adapter plates product-specific could be mounted (see Figure 45). This minimized dedicated tooling while allowing multiple part orientations.

Due to inherent limitations of the View 1200 it will support inspection activities normally assigned to our resident coordinate measuring machine, not replace it. These limitations are basically due to programming vs. Quantity tradeoffs and physical limitations of the equipment (ie; it's ability to place the lens at the required location to aquire an image without interfering with a part feature such as a web or wall). Because this equipment in effect becomes support to the existing receiving inspection function no change to the IDEF Model is realized. The as-is IDEF Model is shown in Figure 46.

4TH ROTATIONAL AXIS WITH TOOLING PLATE



87-0422

Figure 45

PERFORM TEST, INSPECT, AND EVALUATE (As-Is)

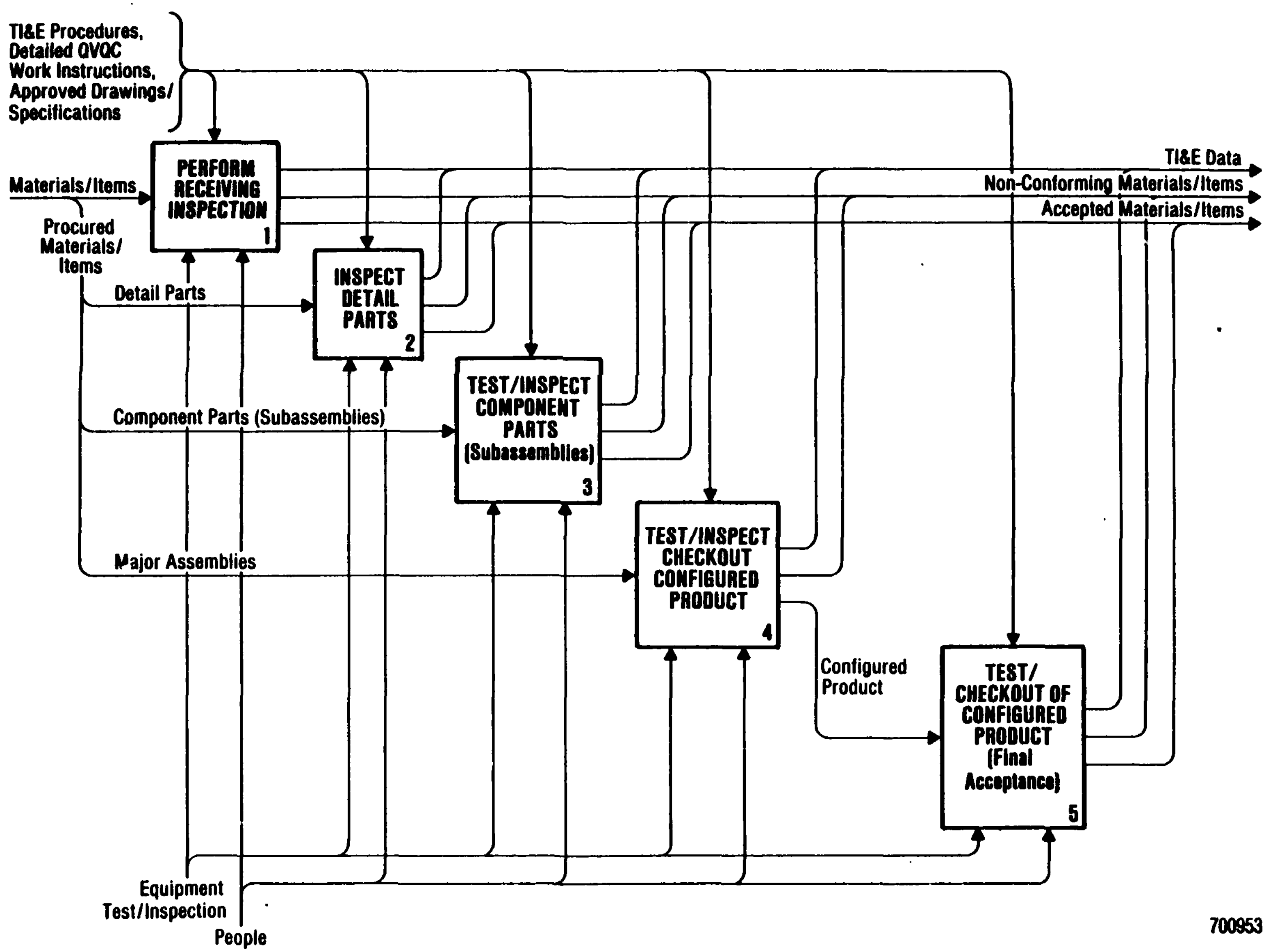


Figure 46A

PERFORM RECEIVING INSPECTION (As-Is)

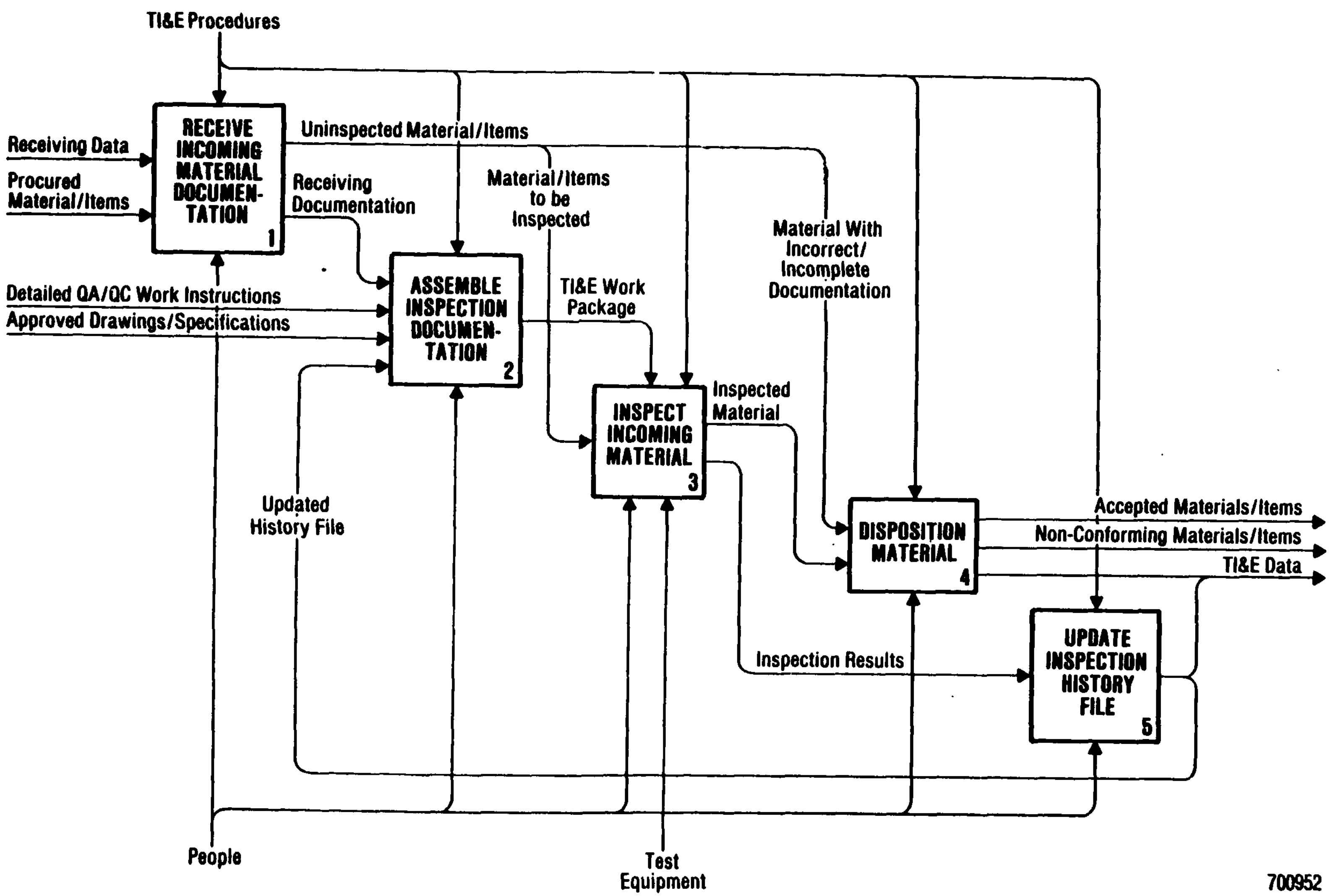


Figure 46B

INSPECT DETAIL PARTS (As-Is)

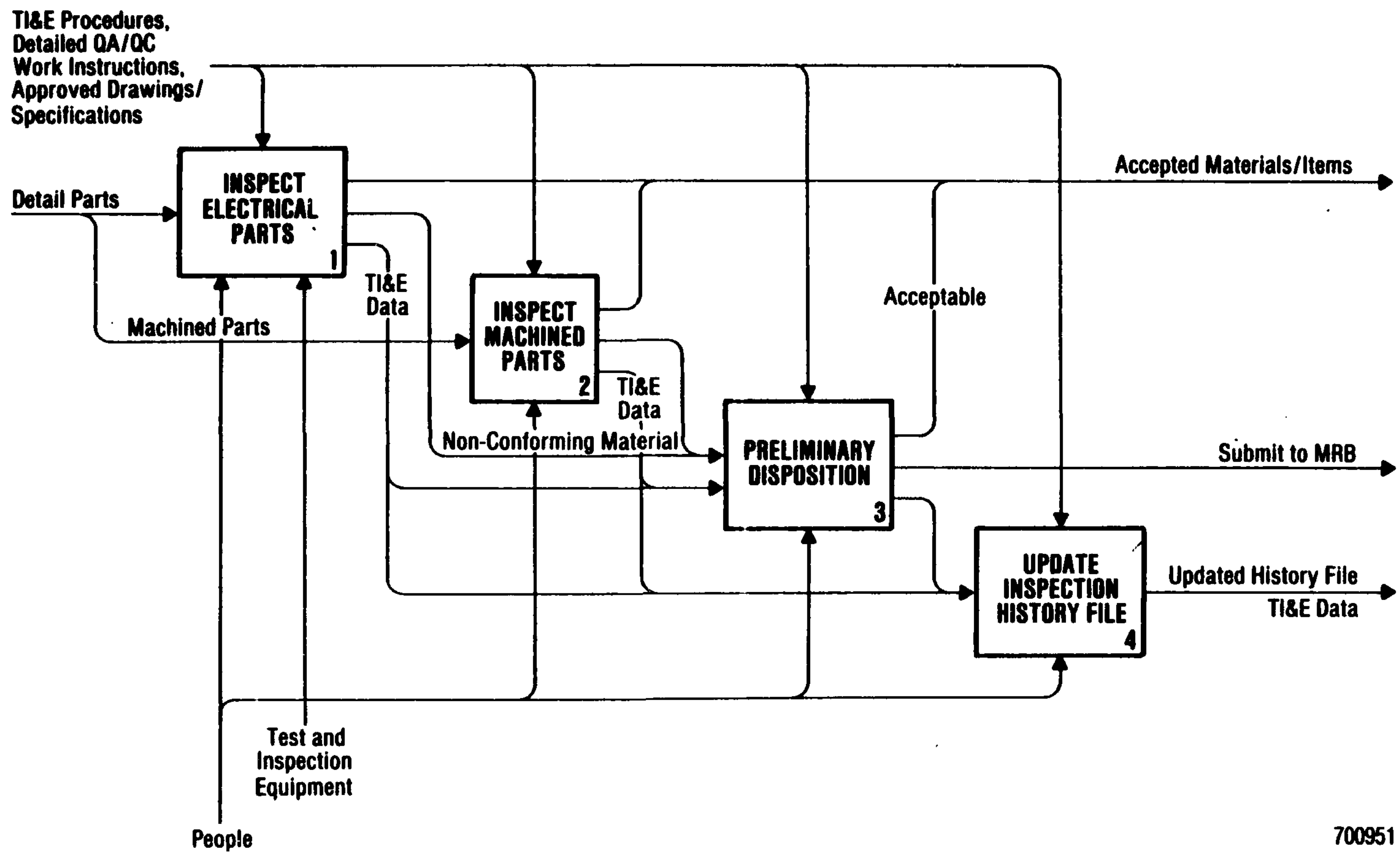


Figure 46C

INSPECT MACHINED PARTS (As-Is)

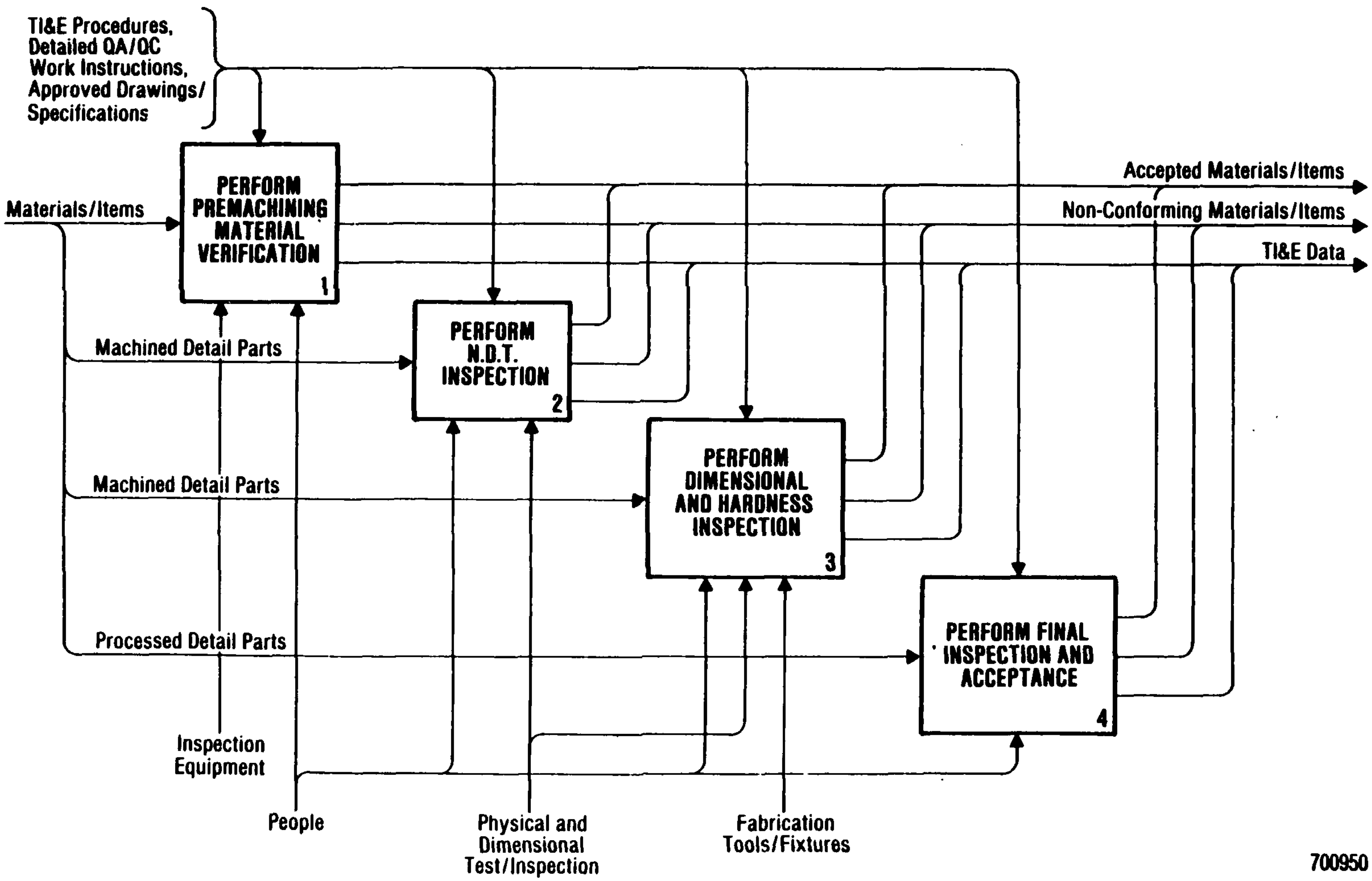


Figure 46D

Delco Electronics

General Motors Corporation
Santa Barbara Operations
6767 Hollister Avenue
Goleta, California 93017

STATEMENT OF WORK

TITLE			SW	AMEND
MECHANICAL INSPECTION CELL - ITM PROJECT 12			E41-001	C
PREPARED BY D. Zielinski	DATE 5/23/85		SHEET 1 OF 14	
APPROVED BY			CONTRACT NO. F33657-80-G-0007	
APPROVED BY			CODE IDENT NO 13160	

AMENDMENT LOG

AMEND	DESCRIPTION	AUTHORITY	DATE	APVD
A	ADDED SECTIONS 2.1.2.4, 2.1.2.5 REVISED PARA 1.2, 2.1.1.5, 2.1.1.6, 2.1.3, 2.1.3.2, 2.1.3.4, 2.1.3.6, 2.1.2.12, 2.1.2.13	DZ	6-12-85	
B	REVISED PARA 2.1.1.5, 2.1.1.6, 2.1.2.1.1, 2.1.2.2.1, 2.1.2.4.1, 2.1.3.2, 2.1.3.3, 2.1.3.6, 2.1.3.8, 2.1.3.9, 2.1.5.1 / ADDED PARA 2.1.2.23, 2.1.2.1.4, 2.2.5.4 / REVISED FIGURE 1	DZ	6-27-85	
C	DELETED PARA 2.7, 2.8, 2.9, 2.1.2.1.4, 2.1.2.2.3 REVISED FIGURE 1	DZ	9-18-85	

NOTE: Technical Directives amending this SOW shall be attached behind this cover sheet.

TABLE OF CONTENTS

1.0 SCOPE

1.1 PURPOSE

This specification outlines equipment requirements for an automated mechanical inspection cell to be used in a Receiving and Inspection department (see Figure 1). This inspection cell shall utilize machine vision and robotic technologies to accomplish this task.

1.2 DOCUMENTS

The following government standards, specifications, and regulations, issued in effect on the date of this contract, or as otherwise stated herein, shall form a part of this statement of work to the extent specified.

Sound Level Specification	GM spec SL1.0
Robotic Safety Standards	Section 28
Basic Electrical Standard	ES1
Screw Thread Standard	FED-STD-428/6
GM Manufacturing Automation Protocol	MAP
Engineering Exhibit	EE-75-S-989

2.0 DESCRIPTION OF ARTICLES AND SERVICES TO BE FURNISHED

2.1 GENERAL

2.1.1 SYSTEM OBJECTIVES

2.1.1.1 The mechanical inspection cell shall use automatic vision and robotic systems to inspect a part for all features normally accomplished manually in a receiving/inspection department. Part features would include lengths, widths, heights, feature locations, hole size and depths, tapped hole sizes and depth , angularity, pockets, slots, grooves and any other feature within he capability of the proposed equipment.

2.1.1.2 The inspection cell shall consist of 1) 3-dimensional vision system station to be used for non-contact gaging of mechanical part features; 2) a robot station that would utilize standard go/no-go thread gages to inspect tapped holes; 3) a system supervisory computer to control, transfer, and store data; 4) a material handling robot system to automatically load and unload each station as required; and 5) a safety system.

2.1.1.3 The inspection cell shall have a working envelope (X, Y, Z) of 18 x 24 x 6 inches and a maximum inspected part weight of 12 lbs.

2.1.1.4 Part fixturing requirements shall be semi-dedicated, allowing for common usage between several classes of parts to be inspected. All fixturing shall be manually loaded and unloaded. Detailed fixturing requirements shall be developed during the final systems development.

2.1.1.5 The system shall provide prompting routines for each function which are easily understood without extensive training. These routines must provide the operator with step by step guidance through all phases of system operation including startup, calibration, limit setting, fault recovery, and maintenance.

2.1.1.6 The inspection cell system shall provide for operator override, data processing, act as a functional/maintenance/safety monitor, and store and control all internal and external data flow. Upon completion of an inspection sequence it would store all results and print out any out-of-tolerance part features and make acceptance or rejection decisions.

2.1.2 INSPECTION CELL SUBSYSTEMS DEFINITION

2.1.2.1 DIMENSIONAL MEASUREMENT STATION

2.1.2.1.1 The 3-dimensional vision system that adequately fulfills the requirements of this inspection cell is a View Engineering Model 1200. It consists of 1) a System Control Unit (SCU), 2) a Data Gathering Unit (DGU), and 3) a part postion monitor. A vision system equivalent to the View 1200 may be used.

2.1.2.1.2 The SCU handles overall control of the vision measurement system. It includes a TV monitor, keyboard, two floppy disk drives (638K each), one 10-megabyte hard disk, and an 8086/8087 16-bit CPU. Data is downloaded to it from the primary computer and supplied software along with built-in algorithms instruct the DGU to perform all required inspections.

2.1.2.1.3 The DGU accomplishes the actual data measurement. It utilizes a high resolution video camera system mounted in the Z axis and an X-Y servo-motor-driven table onto which the part to be inspected is mounted. Since the X and Y dimensions are in the same plane, the planar dimension is established by the distance the table travels plus the camera's interpretation of the edge of the surface feature being inspected. A built-in algorithm establishes the planar dimension that has been checked. The dimension along the Z axis is a function of the focal length of the camera. One pla[illegible] established as the zero or reference point, with the [illegible] being a new plane requiring a new focal length. The distance the fixed focal length camera moves along a Z axis determines the Z dimension of the part features being examined.

2.1.2.1.4 System accuracy requirement shall be $\pm$ .00025 inches minimum in all axes.

2.1.2.2 THREAD INSPECTION STATION

2.1.2.2.1 Tapped hole inspection will be accomplished by using Robotic Thread Gaging. This system consists of a robot, robot controller, and end effector tooling that will use go/no-go thread gages to inspect threaded holes (#2 through 1/4 inch) for correct size, class and thread length.

2.1.2.2.2 End effector tooling shall contain a motorized spindle (if not supplied with robot) capable of driving thread gage tooling, a torque sensor, and a rotational measurement device. The end effector shall be capable of sensing go/no-go torque conditions consistent with standard tapped hole inspection processes per FED-STD-428/6.

2.1.2.2.3 Alignment of the end effector tooling to the tapped hole shall be adequate enough to guarantee that 95% of any torque monitored will represent true torque values and not be due to side loading.

2.1.2.2.4 The end effector shall have a rotational position accuracy of $\pm 45^\circ$.

2.1.2.2.5 The end effector shall have automatic tool changing capability.

2.1.2.3 SAFETY SYSTEM

2.1.2.3.1. The inspection cell shall have a safety system that will automatically shut down all operations in areas accessible by operating robots when entered by any person. Alarm annuciators shall be provided to indicate the occurrence of a safety violation.

2.1.2.3.2 A flashing indicator light will be on when the system is operating.

2.1.2.4 MATERIAL HANDLING ROBOT

2.1.2.4.1 A material handling robot system shall be designed into the inspection cell to accomodate parts transfer between the in/out, Thread Inspection, and Dimensional Inspection Stations. During an inspection sequence, it will also facilitate part reorientation when commanded by the system's controller. This robot system will also be required to act as a parts platform for the Thread Inspection Station minimizing the requirement for worksurface tooling.

2.1.2.4.2 The material handling robot system shall consist of a robot(s), controller, and end-of-arm tooling (EOAT). This system shall be capable of delivering a part (12 lbs. maximum) to worksurface tooling with sufficient positional accuracy to insure that a smooth and non-binding condition occurs.

2.1.2.4.3 The EOAT shall have an automatic tool change capability and will be designed to handle a family of parts minimizing any unique part handling conditions.

2.1.2.5 SYSTEM SUPERVISORY COMPUTER (SSC)

2.1.2.5.1 A computer shall be integrated into the inspection cell and will provide for overall cell control. It will be capable of interacting with all other equipment listed within this specification without adversely effecting the inspection cell performance or intended functions.

2.1.2.5.2 The SSC shall provide for operator override, act as a functional/maintenance/safety monitor, and store and control all data entering or leaving the inspection cell. The computer's inspection data base will also have a manual programming capability.

2.1.3 SEQUENCE OF OPERATIONS

During the initial development phase it will be assumed that all part fixturing will be manually loaded into each station of the inspection cell. Typical sequence of events for a part requiring both dimensional and tapped hole inspection is summarized below. Detailed part transfer requirements shall be developed during final systems development.

2.1.3.1 SSC is loaded with a program.

2.1.3.2 Application program required for dimensional inspection is downloaded to the dimensional inspection station System Control Unit. The part is transferred to the X-Y platform part fixturing by the material handling robot.

2.1.3.3 The dimensional inspection sequence is started.

2.1.3.4 Prompting of the material handling robot by the computer will be desired if part orientation changes are required.

2.1.3.5 After inspection of the part is complete, data is transferred back to the SSC.

2.1.3.6 Parts are then transferred from the Dimensional Inspection station and refixtured onto the Thread Inspection Station work surface (or held by material handling robot).

2.1.3.7 The tapped hole inspection is started.

2.1.3.8 Robot will select proper thread gage per downloaded application program.

2.1.3.9 Robot will center tooling wih tapped hole. Located on the hand of the robot is a 6 axis force sensor which in addition to measuring torque can sense the required compliance to reposition the robot. This will minmize any binding experienced by the tooling and thereby give truer torque measurements.

2.1.3.10 When centering of the thread gaging and tapped hole is accomplished the drive motor will be commanded to reverse rotate for 1.5 turns. This will insure that the gage and the part being inspected are not cross threaded.

2.1.3.11 Thread gaging begins. Gage is driven into part while torque is monitored.

2.1.3.12 Should gage meet resistance (increased torque), motor would be commanded to stop. Depending on whether the gaging is "go" or "no-go", a decision would have to be made. If a "go" gage is used the system would reverse and count the number of revolutions it takes to extract the tooling, thus determining the thread length. If a "no-go" gage is used, it should meet resistance by the third entry revolution. (The system will be required to inspect as many as eight standard and helicoil thread sizes per part [#2, #4, #6, #8, 2 @ #10, 2 @ 1/4"] with each possibly of being a Class 2 or Class 3 thread. A "go" and "no-go" gage is required for each condition [64 gages total]).

2.1.3.13 Material handling robot prompting by the controller will be required if part orientation changes are required.

2.1.3.14 After completion of a particular gage size inspection sequence the controller will command a tool change and the inspection process continues until the part is fully inspected.

2.1.3.15 After part inspection is complete, all data is transferred from the robot to the SSC and an inspection report printout identifying all discrepancies for the part is generated.

2.1.4 SYSTEM CYCLE TIME AND THROUGHPUT

The system throughput must be sufficient to complete each inspection cycle on a continuous basis. The inspection cycle shall include the following:

a. Sensor Image Formation and Transmission
b. Image Processing
c. Feature Measurement and Associated Calculations
d. Tapped Hole Gaging Data
e. Storage of Measurement Data
f. On-Line Reports: Individual Inspection Reports generated (printed) at a sufficient throughput to maintain report synchronization (real time) with the parts as they exit from the inspection cell or substations.

2.1.5 EXPANSION CAPABILITY

2.1.5.1 The inspection system shall be designed to include an expansion capability. This expansion shall be accomplished through the addition of dimensional inspection, vision, robotic thread inspection and/or material handling robots. The expansion shall not involve the replacement of existing computers or inspection equipment.

2.1.5.2 The inspection system shall be capable of receiving operational data from an intraplant network and returning measurement data to that network. The electrical standard shall be IEEE-802 token passing bus or as minimum RS-422. The protocol shall be the GM MAP standard which is based on current ISO, IEEE and NBS standards for local area networks.

2.2 OPERATING SYSTEM SOFTWARE

2.2.1 GENERAL REQUIREMENTS

2.2.1.1 The system software shall include an interactive operating system which guides the operator through each of the inspection station functions. The operating system shall provide a menu of selectable system functions. Prompting routines which are easily understood shall be used to direct the operator in a step by step manner through the completion of each system function.

2.2.2 SYSTEM INITIALIZATION

2.2.2.1 The system shall perform diagnostic checks on all computer and processing equipment including CPU boards, memory devices, I/O interfaces (discrete, analog and serial ports), power supplies, sensors and peripheral devices (reference section 2.2.7).

2.2.2.2 A prompting routine shall be provided to direct the operator through the initialization process.

2.2.3 MEASUREMENT CONFIGURATION

2.2.3.1 Configuration data must be stored on a non-volatile memory device that is readily available for alteration and can be loaded directly during system initialization reference section 2.2.2.

2.2.3.2 Dimensional measurement programs required per section 2.1.2.1 dimensional measurement station.

2.2.3.3 Tapped hole measurement programs required per section 2.1.2.2 tapped hole inspection station.

2.2.4 SYSTEM CALIBRATION

2.2.4.1 The manpower and level of technical expertise to perform system calibration must be plant personnel compatible and shall not require assistance. Calibration procedures shall be automatic and must be designed for easy implementation under the limited time constraints associated with production conditions.

2.2.4.1 Set up and system calibration data must be stored on a non-volatile memory device that is readily available for alteration, can be loaded directly during system initialization (reference section 2.2.2) and can be accessed for verification, replacement or recalibration functions.

2.2.5 MEASUREMENT DATA STORAGE

The measurement data produced by the inspection station must be stored in a data base which meets the following system requirements.

2.2.5.1 Capacity for 150 dimensioned features per part, at an inspection rate of 100 parts per day over a five day period.

2.2.5.2 Part number, serial number, title, lot number and program code shall identify each part inspected. Each of these identifiers shall not exceed a 25 alpha/numeric character.

2.2.5.3 Date and time of system operation.

2.2.5.4 Upon completion of an inspection sequence, a data field shall be created that contains all the necessary information for report generation.

2.2.6 INSPECTION REPORTS

2.2.6.1 The generation of inspection reports for each part shall be sufficient to maintain report printing synchronization (real time) with each part as it indexes from the inspection cell. Reports shall also be made available if requested manually.

2.2.6.2 All reports shall be available for output in either the systems console (CRT) or printer.

2.2.6.3 Individual inspection reports shall contain:

		# OF ALPHANUMERICS
a.	Identifier	19
b.	Program Number	10
c.	Serial Number	7
d.	RIP Number	7
e.	Defect Code	10
f.	Date and Time	11
g.	Inspection point discrepancies	(sec. 2.2.5.1)

2.3 SYSTEM HARDWARE

2.3.1 GENERAL REQUIREMENTS

2.3.1.1 The system shall conform to Delco Systems electrical specifications and workmanship standards.

2.3.1.2 Readily available (off the shelf) materials and components shall be used wherever possible. Any single source items used in the system must be clearly identified and a statement of availability supplied.

2.3.1.3 Troubleshooting shall be facilitated by the following considerations.

a. Self-diagnostics that provide fault detection and reporting down to the major component level.

b. Easy access to all mechanical and electrical components.

c. Minimization of unique board proliferation.

d. Attention to modular design

2.3.1.4 The system console (CRT) and printer must be mounted in enclosures which meet all of the environmental conditions stated in this specification.

2.3.1.5 All enclosures must have an automatic disconnect feature which disengages power when the internal enclosure temperature reaches the manufacturer's specified limit of the device most sensitive to elevated temperature. The power disconnection feature must be designed to provide a controlled power shut-down, which maintains the integrity of the inspection cycle that is in process at the time the power failure occurred.

2.3.1.6 On power up and power down conditions, all outputs shall hardware default to a safe off state and remain so until commanded differently from the controlling processor.

2.3.1.7 All dc power supply outputs shall have short circuit, overvoltage protection and adequate filtering.

2.3.1.8 There shall be an additional 120 VAC, 10 amp rated wall duplex receptacle for powering test equipment, etc., fused separately from the main circuit breakers, noise isolated from the computer/processing equipment and mounted inside the main control enclosure.

2.3.1.9 All receptacles, fuses, indicators, modules, circuit boards and test points shall be permanently labeled.

2.3.1.10 All PROM based computer/processors shall have on-line PROM checksum error detection.

2.3.1.11 Provisions shall be made to attach 4 AWG ground strap between all panels and subpanels to earth ground.

2.3.1.12 The main operating system computer must have a hardware real time clock.

2.3.2 ENVIRONMENTAL REQUIREMENTS

2.3.2.1 The inspection system must operate at full accuracy under the environmental conditions of the Receiving/Inspection Department, including the following.

a. Ambient temperature range of 62°F to 90°F.
b. Humidity levels from 30% to 100% (non-condensing).
c. Airborne contaminants such as dust and oils.
d. RFI and EMI electrical noise both conducted and radiated.

2.3.2.2 Plant power source supplying standard 120 VAC AND 220 VAC.

INSPECTION RESULTS

PN: 7568174-001
SN: 0000001
RIP: 0000001

Inspection Date: 13/02/00
Inspection Time: 10:25

Current Date: 13/02/00
Current Time: 10:33

ITEM NUMBER	DIMENSION	NOMINAL	TOLERANCE (+/-)	ACTUAL	DEVIATION (Act-Nom)	THREAD DEPTH (in) Nominal	Tol.(+/-)	Actual	NO-GO DEPTH (rev) Actual (Min 3)	THREAD SIZE
14	X (in)	5.8188	.0004	5.8189	.0000	.20	.01	.11		6-32 2B
	Y (in)	14.8685	.0004	14.8690	.0005					
	Z (in)	.3157	.0100	.3045	-.0111					
	THETA(deg)	90.0000	.0085	90.0009	.0009					
15	X (in)	5.8102	.0004	5.8103	.0000					
	Y (in)	13.6498	.0004	13.6503	.0005					
	Z (in)	.6307	.0100	.6266	-.0041					
	THETA(deg)	76.2160	.0085	76.2139	-.0020					
16	X (in)	5.7979	.0004	5.7980	.0000					
	Y (in)	12.4954	.0004	12.4959	.0004					
	Z (in)	1.2948	.0100	1.2962	.0014					
	THETA(deg)	60.9140	.0085	60.9119	-.0020					
17	X (in)	5.7875	.0004	5.7876	.0000					
	Y (in)	11.3767	.0004	11.3771	.0004					
	Z (in)	2.4479	.0100	2.4516	.0036					
	THETA(deg)	42.8670	.0085	42.8599	-.0070					
18	X (in)	5.7799	.0004	5.7800	.0000					
	Y (in)	10.8054	.0004	10.8058	.0004					
	Z (in)	3.6130	.0100	3.6185	.0054					
	THETA(deg)	28.0260	.0085	28.0219	-.0040					
19	X (in)	5.7755	.0004	5.7756	.0000					
	Y (in)	10.4887	.0004	10.4891	.0004					
	Z (in)	5.1757	.0100	5.1818	.0061					
	THETA(deg)	9.9650	.0085	9.9639	-.0010					
20	X (in)	5.7746	.0004	5.7747	.0000					
	Y (in)	10.6394	.0004	10.6398	.0004					
	Z (in)	6.0206	.0100	6.0188	-.0018					
	THETA(deg)	.4620	.0085	.4619	-.0000					
21	X (in)	5.7746	.0004	5.7747	.0000					
	Y (in)	10.7553	.0004	10.7557	.0004					
	Z (in)	6.0603	.0100	6.0594	-.0008					
	THETA(deg)	.0000	.0085	-.0000	-.0000					
22	X (in)	5.7746	.0004	5.7747	.0000					
	Y (in)	20.3815	.0004	20.3823	.0008					
	Z (in)	6.0583	.0100	6.0594	.0011					
	THETA(deg)	.0000	.0085	-.0000	-.0000					

```
PROGRAM TI_V2

 VAR
  TAP_SIZE:INTEGER      -- CURRENT TAP SIZE
  PATH_LEN:INTEGER      -- CURRENT PATH LENGTH
  PITCH:INTEGER      -- THREAD PITCH
  DEPTH:REAL      -- DEPTH OF THREAD TO BE TESTED
  P1:POSITION  -- DUMMY POSITION VARIABLE
  PFLAG:INTEGER      -- PFLAG=1 INSPECT A TAPPED HOLE, PFLAG=0:MOVE ONLY
  D:INTEGER
  CLOCK:INTEGER
  X,Y,Z,W,P,R,E,F,T:REAL
  XX:REAL
  YY:STRING[22]
  VAR1:STRING[4]
  MS:REAL       --  MS IS THE NUMBER OF ROTATIONS/SEC OF EOAT MOTOR
  PERCH:POSITION

-- THIS ROUTINE SETS THRESHOLD IN TORQUE COMPARATOR CIRCUIT
ROUTINE SET_THRESH(TAP_SIZE:INTEGER) FROM TI_V2EXT

ROUTINE CHANGE_TAP   -- CHANGES EOAT TAP. CALLED FROM MAIN
BEGIN
-- NOT YET IMPLEMENTED
  --WRITE F5 ('CURRENT TAP SIZE: ',TAP_SIZE,CR)
  --WRITE F5 ('CURRENT PATH LEN: ',PATH_LEN,CR)
  --WRITE F5 ('THREAD DEPTH: ',DEPTH,CR)
  --WRITE F5 ('E: ',E,CR)
  --WRITE F5 ('THREAD PITCH: ',PITCH,CR)
END CHANGE_TAP

ROUTINE CALL_MC  -- ISSUES EOAT MOTOR CONTROLLER
-- COMMANDS TO INSERT AND EXTRACT TAP. CALLED FROM INSP_HOLE
BEGIN
DOUT[12]=ON
DELAY 250
PULSE DOUT[10] FOR 8
DELAY 250
DOUT[8]=OFF
DOUT[7]=OFF
--    GAGE INSERTION
WRITE F2 (';')
DELAY 250
WRITE F2 ('PR',XX::6::0,';')
DELAY 250
OPEN HAND 2
DELAY 500
WRITE F2 ('DH;')
DELAY 250
PULSE DOUT[10] FOR 8
DELAY 500
-- FIND TIME REQUIRED TO THREAD HOLE
CLOCK=0
CONNECT TIMER TO CLOCK
WRITE F2 ('BG;')
DELAY 5000
CLOSE HAND 2
WHILE DIN[1]=OFF DO
  HOLD
ENDWHILE
```

```
WRITE F2 ('ST;')
DELAY 250
DISCONNECT TIMER CLOCK
--   GAGE EXTRACTION
DOUT[12]=OFF
WRITE F2 (';')
DELAY 250
WRITE F2 ('VM;')
DELAY 250
WRITE F2 ('DH;')
DELAY 250
WRITE F2 ('DF;')
DELAY 250
PULSE DOUT[10] FOR 8
DELAY 250
WRITE F2 ('BG;')
DELAY 1000
UNHOLD
IF (CLOCK/1000. < PITCH*0.0787/MS) THEN
  T = 0.0175*MS*CLOCK/PITCH
  SHIFT(P1,VEC(0.,0.,T))
ELSE
  SHIFT(P1,VEC(0.,0.,2.0))
ENDIF
WITH $SPEED=E MOVE TO P1
WHILE DIN[1]=OFF DO
  HOLD
ENDWHILE
WRITE F2 ('ST;')
DELAY 250
PULSE DOUT[10] FOR 8
DELAY 250
WRITE F2 ('TP;')
READ F2 (YY)
WRITE F5 (YY,CR)
UNHOLD
END CALL_MC

ROUTINE INSP_HOLE   -- INSPECT THREADED HOLE
BEGIN
--WRITE F5 (P1,CR)
XX=PITCH*DEPTH*(-4000.0)
DOUT[9]=OFF  -- MOTOR CONTROLLER HARD RESET INITIALIZATION
SET_THRESH(TAP_SIZE)
SHIFT(P1,VEC(0.0,0.0,5.0))
MOVE TO P1
SHIFT(P1,VEC(0.0,0.0,-5.0))
WITH $SPEED=500./$PRGOVERRIDE MOVE TO P1
CALL_MC
SHIFT(P1,VEC(0.0,0.0,5.0))
MOVE TO P1
END INSP_HOLE



BEGIN
-- OPEN DATA FILES AND INITIALIZE PERTINATE VARIABLES
FOR D=1 TO 13 DO  --CLEAR SCREEN
  WRITE (CR)
ENDFOR
```

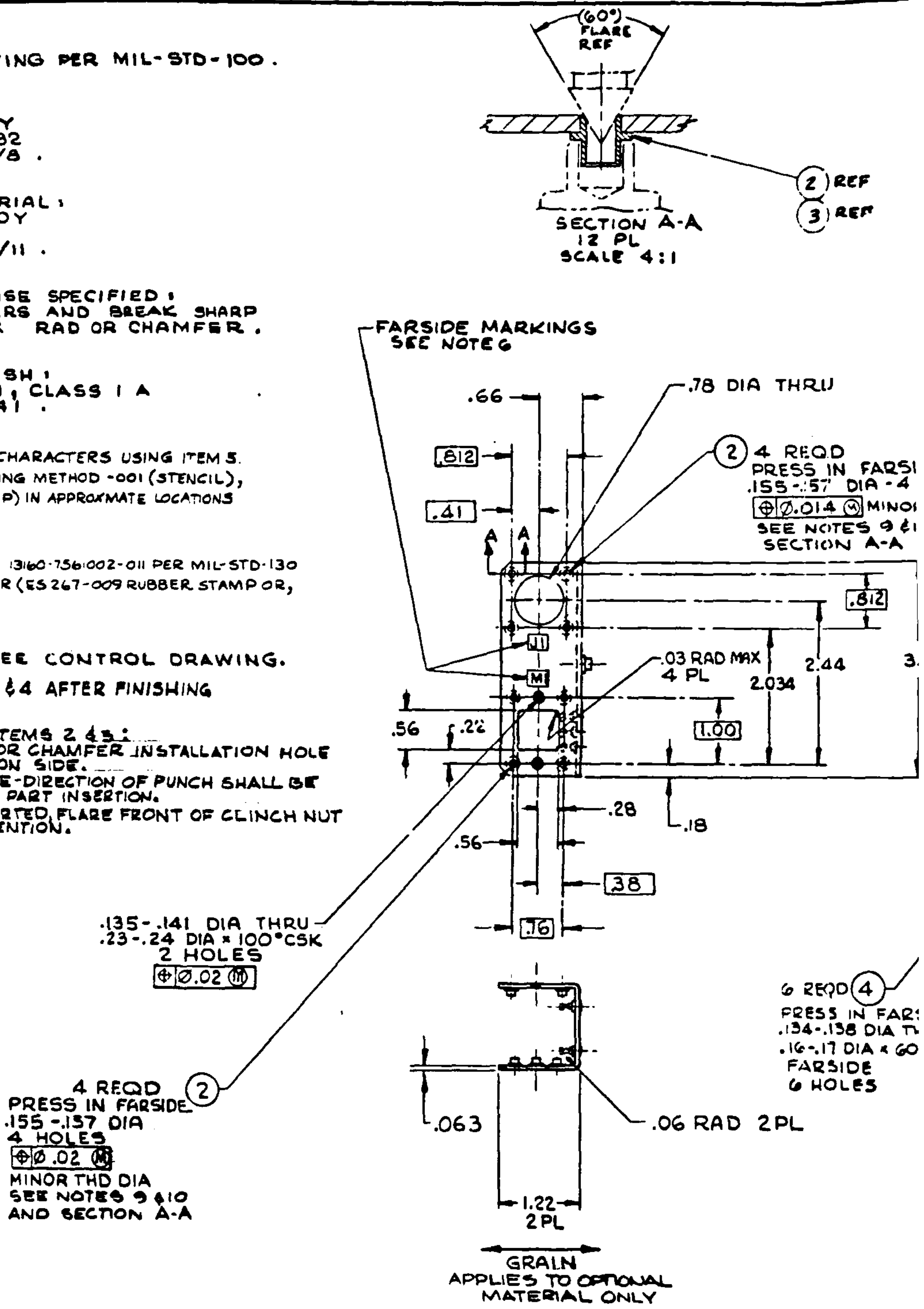
```
VAR1='PSTR'
$MOTYPE=LINEAR
$TERMTYPE=FINE
$SPEED=200
MS = 0.25   --  INLAND MOTOR TURNS AT 1/4 RPS
OPEN FILE F2 ('RW,IA','CO:')
OPEN FILE F5 ('RW','DATA.DT')
OPEN FILE F6 ('RO','TAP_DATA.DT')
KCL('COMM SET BAUD CO 300')
PERCH=POS(1030.0,105.0,650.0,-180.0,0.0,-180.0,'N')
MOVE TO PERCH

-- SCAN DATA FILE TO OBTAIN EACH TAP SIZE AND CORRESPONDING HOLES
READ F6 (TAP_SIZE,PITCH,DEPTH,PATH_LEN,D)
WHILE NOT EOF(F6) DO
  $PRGOVERRIDE=D
  E = MS*2540./(PITCH*D)
  CHANGE_TAP
  FOR D=1 TO PATH_LEN DO
    READ F6 (PFLAG,X,Y,Z,W,P,R)
    P1 = POS(X,Y,Z,W,P,R,'N')
    IF (PFLAG=1) THEN
       INSP_HOLE
    ELSE
       MOVE TO P1
    ENDIF
  ENDFOR
  READ F6 (TAP_SIZE,PITCH,DEPTH,PATH_LEN,D)
ENDWHILE

MOVE TO PERCH
CLOSE FILE F5
VAR1='FRDY'
WHILE (VAR1 <> 'FDON') DO
ENDWHILE
VAR1='PDON'
END TI_V2
```

```
PROGRAM TI_V2EXT

ROUTINE SET_THRESH(TAP_SIZE:INTEGER)
BEGIN
SELECT TAP_SIZE OF
  CASE (14) :    -- 5.1 IN-OZ
    DOUT[1]=OFF
    DOUT[2]=OFF
    DOUT[3]=ON
    DOUT[4]=ON
    DOUT[5]=OFF
    DOUT[6]=OFF
  CASE (10) :    -- 3.5 IN-OZ
    DOUT[1]=OFF
    DOUT[2]=OFF
    DOUT[3]=ON
    DOUT[4]=ON
    DOUT[5]=ON
    DOUT[6]=OFF
  CASE (8) :    -- 3.0IN-OZ
    DOUT[1]=ON
    DOUT[2]=OFF
    DOUT[3]=OFF
    DOUT[4]=OFF
    DOUT[5]=OFF
    DOUT[6]=ON
  CASE (6) :    -- 2.5 IN-OZ
    DOUT[1]=OFF
    DOUT[2]=ON
    DOUT[3]=ON
    DOUT[4]=OFF
    DOUT[5]=OFF
    DOUT[6]=ON
  CASE (4) :    -- 2.0 IN-OZ
    DOUT[1]=ON
    DOUT[2]=ON
    DOUT[3]=OFF
    DOUT[4]=ON
    DOUT[5]=OFF
    DOUT[6]=ON
  CASE (2) :    -- 1.5 IN-OZ
    DOUT[1]=OFF
    DOUT[2]=OFF
    DOUT[3]=OFF
    DOUT[4]=OFF
    DOUT[5]=ON
    DOUT[6]=ON
  ELSE :
ENDSELECT
END SET_THRESH

BEGIN
END TI_V2EXT
```

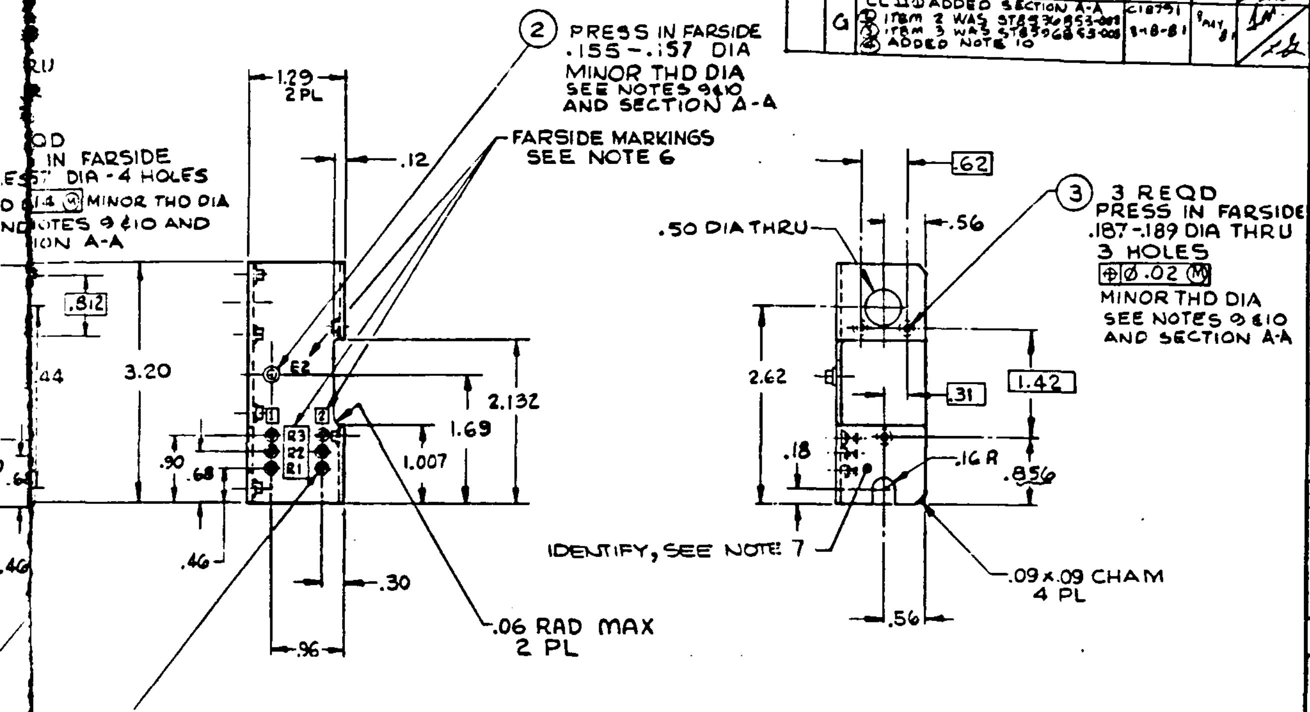
```
PROGRAM TI_CAL
 VAR
 K:STRING[22]
 BEGIN
 K = 'COMM SET BAUD CO 300' ---MOTOR CONTROLLER
 KCL (K)
DOUT[1]=ON
DOUT[2]=ON
DOUT[3]=ON
DOUT[4]=ON
DOUT[5]=ON
DOUT[6]=OFF
DOUT[7]=OFF   --ENABLE BUFFER
DOUT[8]=OFF ---- CLEAR BUFFER
DELAY 250
 OPEN FILE F1 ('RW,IA','CO:')
 WRITE F1 (';')
 DELAY 250
 WRITE F1 ('VM;')
 DELAY 250
 WRITE F1 ('PL 0;')
 DELAY 250
 WRITE F1 ('ZR 254;')
 DELAY 250
 WRITE F1 ('GN 3;')
 DELAY 250
 WRITE F1 ('SP 1000;')
 DELAY 250
 WRITE F1 ('AC 500;')
 DELAY 250
WRITE F1 ('DH;')
DELAY 250
 WRITE F1 ('PR -12000;')
 DELAY 250
PULSE DOUT[10] FOR 8
 WRITE F1 ('BG;')
 DELAY 8000
 DOUT[8]=ON---CLEAR BUFFER
DELAY 250
 DOUT[8]=OFF
DELAY 500
DOUT[7]=ON --- ENABLE BUFFER
DELAY 250
DOUT[7]=OFF --- DISABLE BUFFER
DELAY 4000
WRITE F1 ('ST;')
PULSE DOUT[8] FOR 8
DELAY 250
WRITE F1 ('DH;')
 END TI_CAL
```

NOTES:

1. INTERPRET DRAWING PER MIL-STD-100.
2. MATERIAL:
   ALUMINUM ALLOY
   5052 TEMPER H32
   SPEC QQ-A-250/8.
3. OPTIONAL MATERIAL:
   ALUMINUM ALLOY
   6061 TEMPER T6
   SPEC QQ-A-250/11.
4. UNLESS OTHERWISE SPECIFIED:
   REMOVE ALL BURRS AND BREAK SHARP EDGES .02 MAX RAD OR CHAMFER.
5. PROTECTIVE FINISH:
   CHEMICAL FILM, CLASS 1 A
   SPEC MIL-C-5541.
6. MARK .12 HIGH BLACK CHARACTERS USING ITEM 5. MARK PER ES 2475 USING METHOD -001 (STENCIL), OR -005 (RUBBER STAMP) IN APPROXIMATE LOCATIONS SHOWN.
7. IDENTIFY WITH PART NO 13160-7561002-011 PER MIL-STD-130 USING ITEM 5. MARK PER (ES 267-009 RUBBER STAMP OR, -001 STENCIL).
8. VENDOR ITEM, SEE CONTROL DRAWING.
9. INSTALL ITEMS 2, 3, & 4 AFTER FINISHING PER NOTE 5.
10. INSTALLATION OF ITEMS 2 & 3:
    A. DO NOT BREAK OR CHAMFER INSTALLATION HOLE EDGE ON INSERTION SIDE.
    B. IF PUNCHED HOLE-DIRECTION OF PUNCH SHALL BE OPPOSITE THAT OF PART INSERTION.
    C. WITH REAR SUPPORTED FLARE FRONT OF CLINCH NUT TO INSURE RETENTION.



REVISIONS					
ZONE	LTR	DESCRIPTION	AUTH	DATE	APPROVED
4-C 5-C	A	CL. II ① DIM. 1.29 WAS 1.286 ② ADDED TRUE POSITION TO .78 DIA. ③ ADDED 'MINOR THD. DIA' TO TRUE POSITION TOL. (ZONES 5-C, 7-A & 1-C)	C 10984	9-16 77	DT / AH
B-1	B	CLASS II ① ADDED ITEM 4 IN P/L & ② RELOCATED HOLES: .46 WAS 1.47, .68 WAS 1.69, .90 WAS 1.91 ③ RELOCATED FARSIDE MARKINGS	C 11179	12-1 77	JRM / AH.
C-3	C	CL II ① IN P/L - ITEM 2 - QTY WAS "8" - ADDED RELATED NOTE & 1.69 DIM.	C 11214	5 DEC 77	RH / AH.
F/0 B2	D	CL II ① RELAX TOLERANCE ② ADD SLOT	C 11372	23 JAN 78	D.A. / D.T.
B,C6	E	CL II ① EXTENDED CENTERLINE THRU SQUARE HOLE	C 12463 7-14-78	17 JUL 78	SOW
	F	CL II ① REVISED REV STATUS BLOCK ② ADDED ITEM 5 TO P/L ③ REVISED NOTES 6 & 7	C18370 11-7-80	1 NOV 80	GK
	G	CL II ① ADDED SECTION A-A ② ITEM 2 WAS ST8936853-001 ③ ITEM 3 WAS ST8396853-005 ④ ADDED NOTE 10	C18791 3-18-81	9 MAY 81	



REV G DWG NO 7561002

REV G DWG NO 7561002

			AR	5		FLAT BLACK	INK, MARKING, EPOXY	MIL-I-43553
			6	4		7557829-001	TERMINAL, STANDOFF	SEE NOTE 8 & 9
			3	3		7564532-007	NUT, SELF-LOCKING, CLINCH	SEE NOTE 8 & 9
			9	2		7564532-004	NUT, SELF-LOCKING, CLINCH	SEE NOTE 8 & 9
			1	1		7561002-001	BRACKET	SEE NOTE 2 & 3
-041	-031	-021	-011	ITEM	CODE IDENT. NO	PART NUMBER	NOMENCLATURE OR DESCRIPTION	SPECIFICATIONS
QUANTITY REQD				LIST OF PARTS AND MATERIALS				

THE PART NUMBER IS THE DRAWING NUMBER AND THE DASH NUMBER THAT APPLIES

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON
2 PLACE DECIMALS ±.01 | 3 PLACE DECIMALS ±.005 | ANGLES ± 3°

MATERIAL: SEE L M

REF: C59 | CHG CONTROL

CONTR NO: F33657-75-C-0310
DRAWN / CHECKER / ENGR / APPD / APPD / DSGN ACTIVITY APPD / OTHER APPROVAL

Delco Electronics
GENERAL MOTORS CORPORATION SANTA BARBARA, CALIFORNIA

TITLE: BRACKET - INSEP ASSY

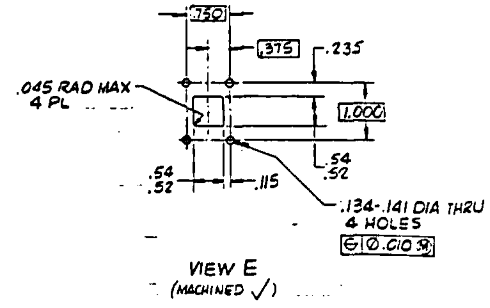
SIZE	CODE IDENT NO.	DWG NO.	REV
D	13160	7561002	G

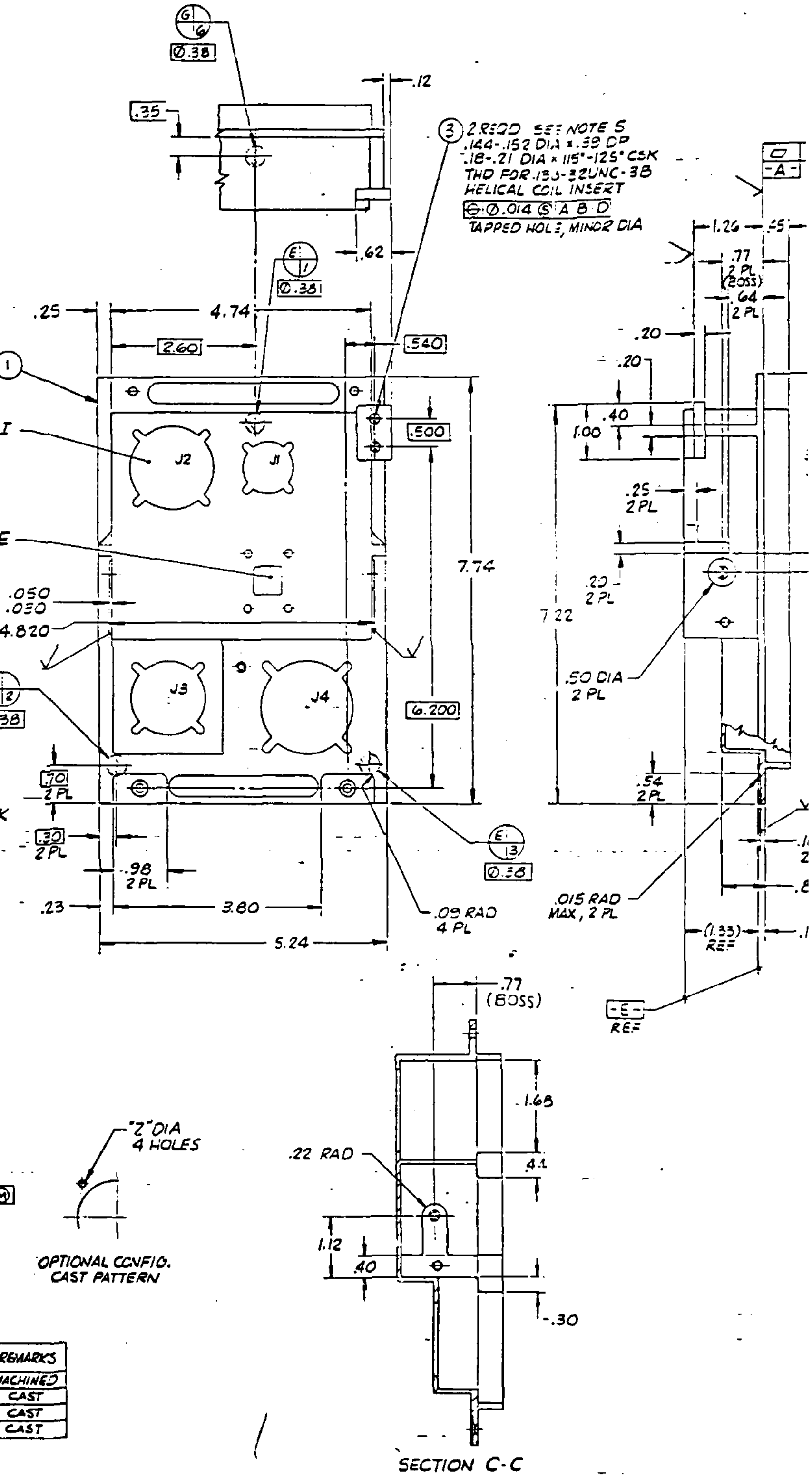
SCALE FULL | WEIGHT | SHEET 1 OF 1

2

NOTES

1. INTERPRET DRAWING PER DOD-STD-100.
2. MATERIAL :
   ALUM ALLOY CASTING
   356 TEMPER T6, QQ-A-596
   OPTIONAL MATL :
   ALUM ALLOY CASTING
   A356 TEMPER T61, QQ-A-596
3. UNLESS OTHERWISE SPECIFIED :
   A. REMOVE BURRS AND BREAK SHARP EDGES .02 MAX RAD OR CHAMFER.
   B. ALL CAST INTERNAL CORNER RADII .08 MAX.
   C. ALL CAST EXTERNAL CORNER RADII .03 MAX.
   D. CAST WALL THICKNESS INCLUDING DRAFT .06-.10
   E. MAX DRAFT 1°.
   F. MACHINED SURFACES DENOTED BY √.
4. INSPECT CASTING PER ITEM 7.
5. INSTALL INSERT 3/4-1 1/2 TURNS BELOW SURFACE AND REMOVE TANG PER ITEM 5.
6. IDENTIFY WITH PART NO. 13160-7565015-011 PER ITEM 6.
7. ALL DIMENSIONS APPLY IN AN UNRESTRAINED POSITION.





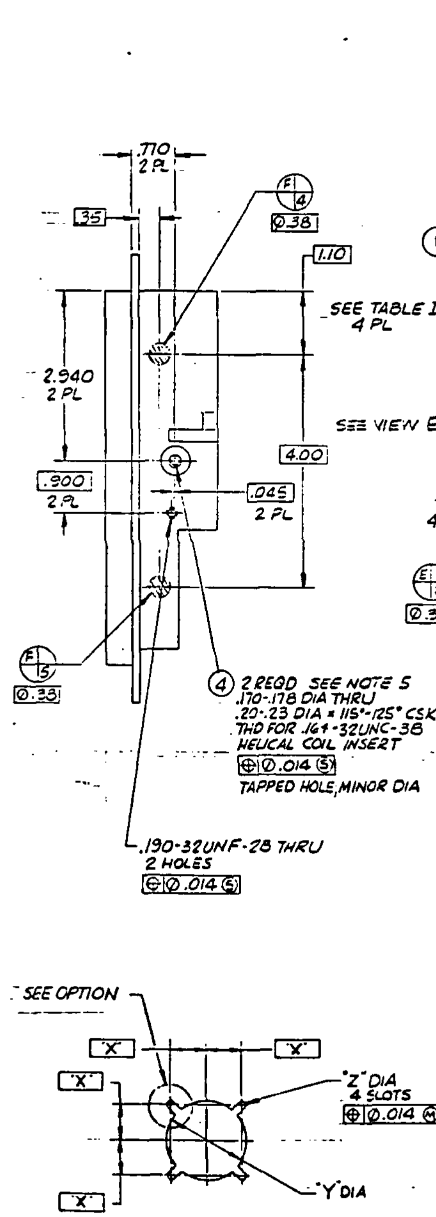
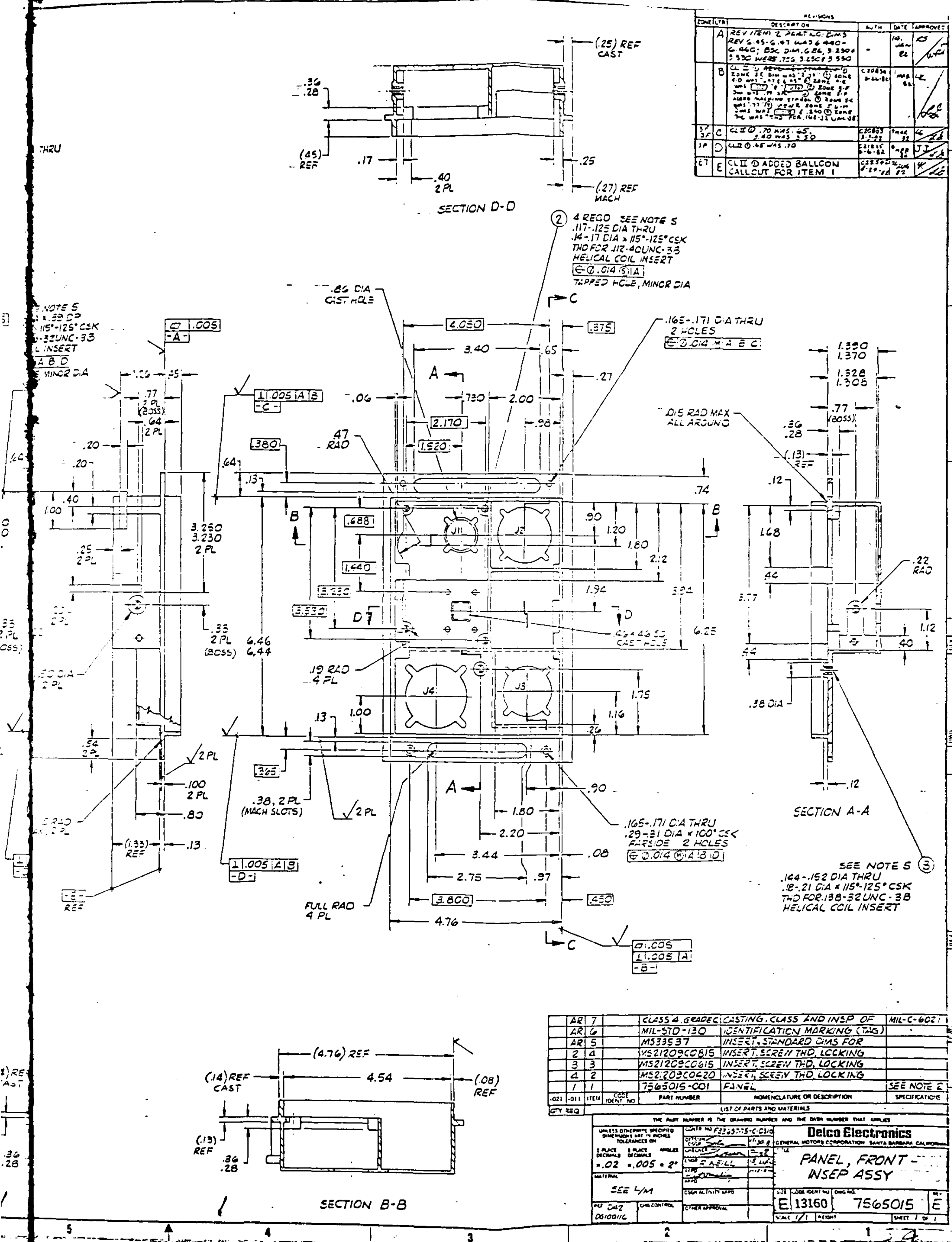


TABLE I
CAST PATTERN

PATTERN	"X" (BSC)	"Y" ±.015	"Z"	REMARKS
J1	.406	.920	.140	MACHINED
J2	.625	1.480	.140	CAST
J3	.578	1.350	.140	CAST
J4	.750	1.700	.166	CAST



REVISIONS

ZONE	LTR	DESCRIPTION	AUTH	DATE	APPROVED
	A	REV ITEM 2 PART NO; DIMS REV 6.45-6.47 WAS 6.440-6.460; BSC DIM .688, 3.230 & 3.530 WERE .755, 3.250 & 3.550	-	10 JAN 82	
	B	CL II ... ZONE 3C DIM WAS ... ZONE 4-D WAS ... ZONE 4-E WAS ... ZONE 3-F DIM WAS .77 2PL ... ZONE 3-F ADDED MACHINE SYMBOL ... ZONE 3-C WAS .77 ... VIEW ZONE 3-D ... DIMS WAS ... & .340 ... ZONE 3-C WAS "THD FOR .138-32 UNC-3B"	C20850 2-26-82	MAR 82	
3F 3F	C	CL II ① .70 WAS .65, 2.40 WAS 2.50	C20803 3-3-82	9 MAR 82	
3F	D	CL II ① .65 WAS .70	C21815 5-6-82	MAR 82	
E7	E	CL II ① ADDED BALLOON CALLOUT FOR ITEM 1	C22342 8-24-82	26 AUG 82	

-021	-011	ITEM	CODE IDENT NO	PART NUMBER	NOMENCLATURE OR DESCRIPTION	SPECIFICATIONS
	AR	7		CLASS 4 GRADE C	CASTING, CLASS AND INSP OF	MIL-C-6021
	AR	6		MIL-STD-130	IDENTIFICATION MARKING (TAG)	
	AR	5		MS33537	INSERT, STANDARD DIMS FOR	
	2	4		MS21209C0815	INSERT, SCREW THD, LOCKING	
	3	3		MS21209C0615	INSERT, SCREW THD, LOCKING	
	4	2		MS21209C0420	INSERT, SCREW THD, LOCKING	
	1	1		7565015-001	PANEL	SEE NOTE 2

QTY REQ — LIST OF PARTS AND MATERIALS

THE PART NUMBER IS THE DRAWING NUMBER AND THE DASH NUMBER THAT APPLIES

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES ON
2 PLACE DECIMALS ±.02 — 3 PLACE DECIMALS ±.005 — ANGLES ± 2°

MATERIAL: SEE L/M

CONTR NO F33657-75-C-0310

ENGR R NEILL

Delco Electronics
GENERAL MOTORS CORPORATION SANTA BARBARA CALIFORNIA

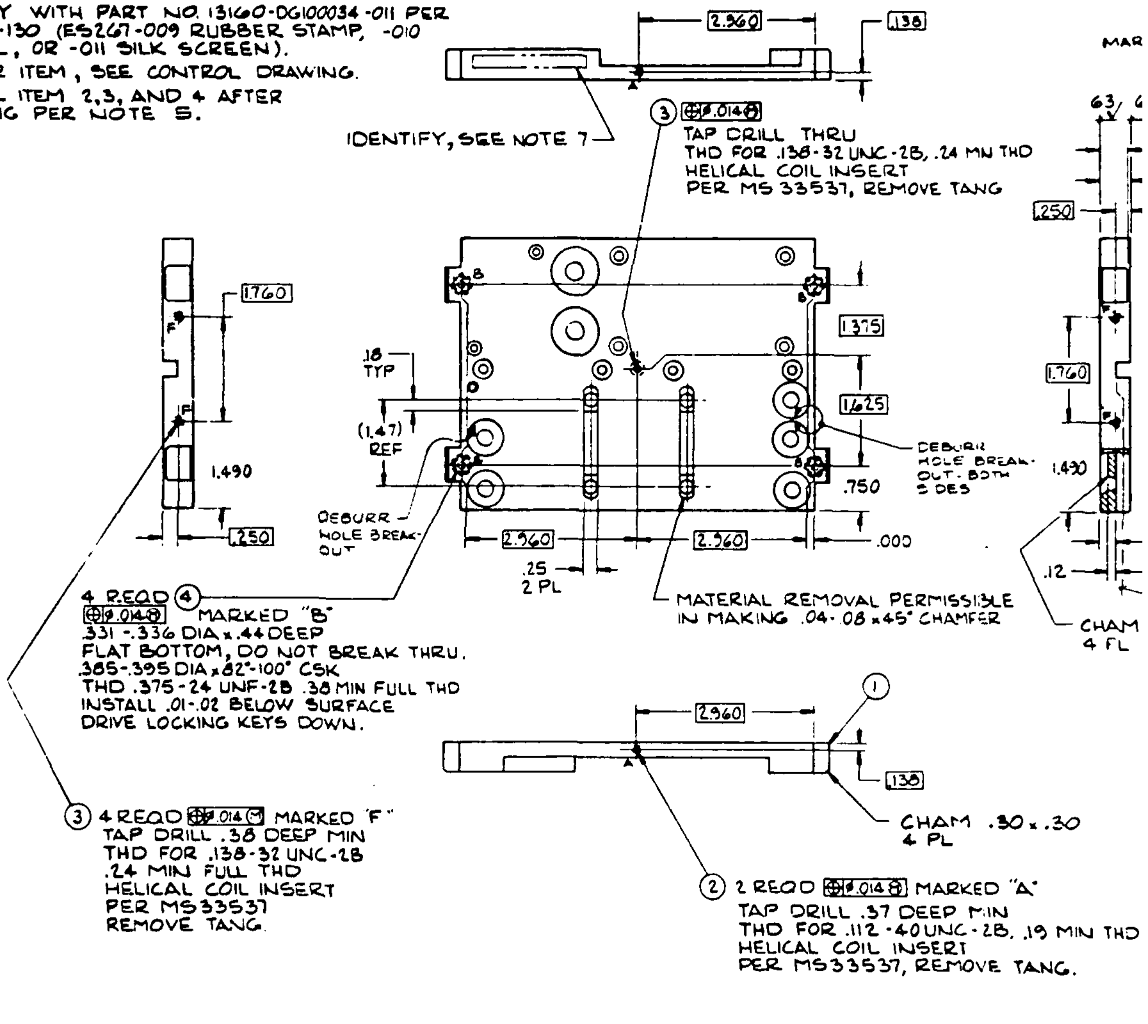
TITLE: PANEL, FRONT - INSEP ASSY

SIZE E — CODE IDENT NO 13160 — DWG NO 7565015 — REV E

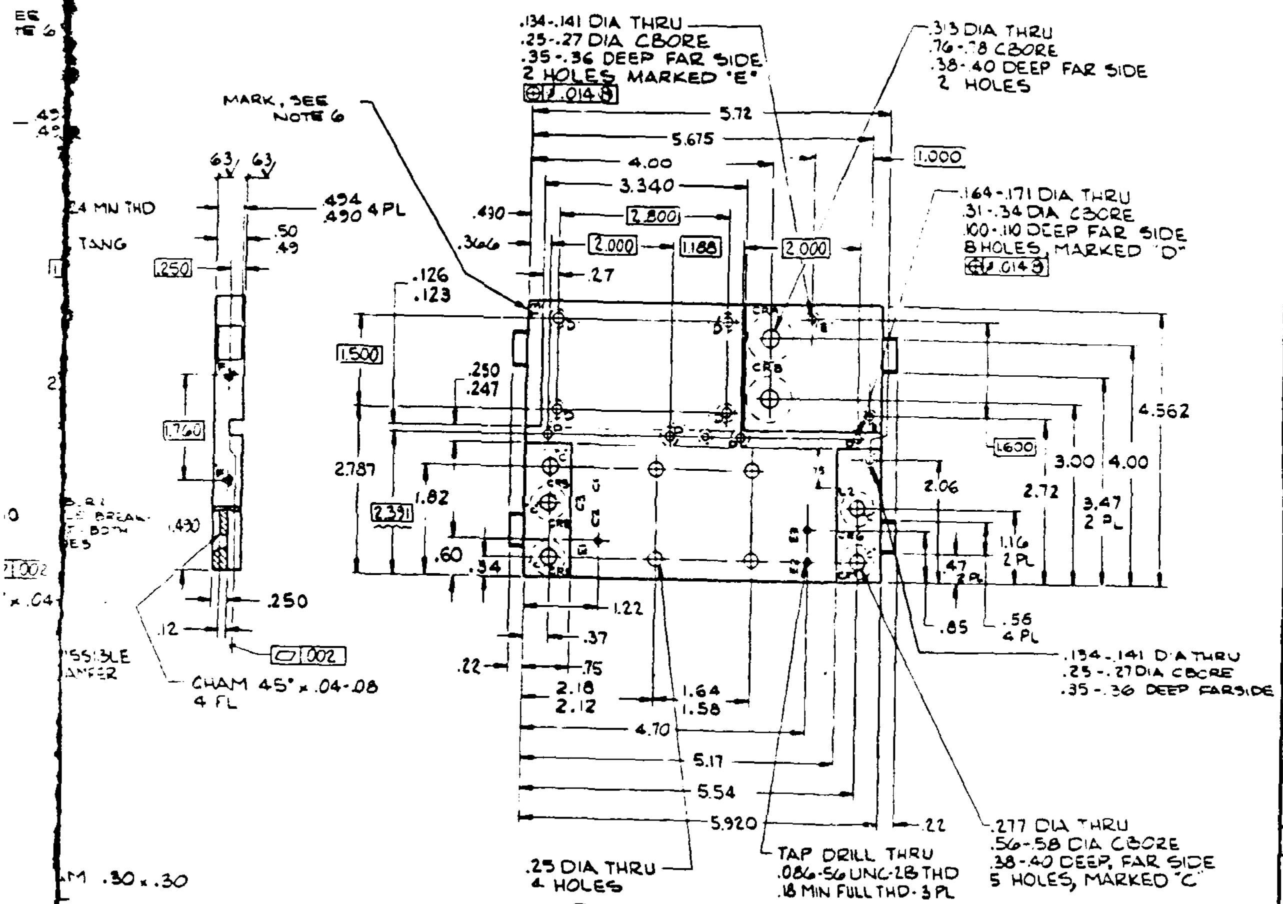
SCALE 1/1 — SHEET 1 OF 1

NOTES:

1. INTERPRET DRAWING PER MIL-STD-100.
2. MATERIAL:
   ALUMINUM ALLOY
   6061 TEMPER T651
   SPEC QQ-A-250/11.
3. OPTIONAL MATERIAL:
   ALUMINUM ALLOY
   2024 TEMPER T351
   SPEC QQ-A-250/4.
4. UNLESS OTHERWISE SPECIFIED:
   REMOVE ALL BURRS AND BREAK SHARP EDGES .02 MAX RAD OR CHAMFER.
5. PROTECTIVE FINISH:
   CHEM FILM ITEM 5.
6. MARK .12 HIGH BLACK CHARACTERS USING INK ITEM 7 PER SPEC ITEM 6 USING METHOD -001 (STENCIL), -002 (SILK SCREEN), OR -005 (RUBBER STAMP) IN APPROXIMATE LOCATIONS SHOWN.
7. IDENTIFY WITH PART NO. 13160-DG100034-011 PER MIL-STD-130 (ES267-009 RUBBER STAMP, -010 STENCIL, OR -011 SILK SCREEN).
8. VENDOR ITEM, SEE CONTROL DRAWING.
9. INSTALL ITEM 2,3, AND 4 AFTER FINISHING PER NOTE 5.



REVISIONS					
ZONE	LTR	DESCRIPTION	AUTH	DATE	APPROVED
	C	REVISED DWG			
E2	D	ADDED "C2" [illegible] .021 [illegible] CBORE [illegible]	-	[illegible]	[illegible]
E3	E	DIMENSIONS 5.675 WAS 5.70 3.340 WAS 3.360, [illegible] WAS .50, .27 WAS .28	-	1/4/80	[illegible]



			AR	7		ST7882520-011	INK, MARKING (FLAT BLACK)	SEE NOTE 8
			REQ	6		ES2475	GENERAL SPEC, MARKING	SEE NOTE 6
			AR	5		MIL-C-5541	CHEMICAL FILM	CLASS 1A
			4	4		7557376-203	INSERT, THD, FLOATING, KEY LOCKED	SEE NOTE 8
			3	3		MS21209C0615	INSERT, SCREW THD, LOCKING	
			2	2		MS21209C0415	INSERT, SCREW THD, LOCKING	
			1	1		DG100034-001	PLATE	SEE NOTE 2&3
-041	-031	-021	-011	ITEM	CODE IDENT NO	PART NUMBER	NOMENCLATURE OR DESCRIPTION	SPECIFICATIONS
QUANTITY REQD.				LIST OF PARTS AND MATERIALS				

THE PART NUMBER IS THE DRAWING NUMBER AND THE DASH NUMBER THAT APPLIES

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON
2 PLACE DECIMALS ±.01 3 PLACE DECIMALS ±.005 ANGLES ±1°

MATERIAL: SEE L/M

REF: D38

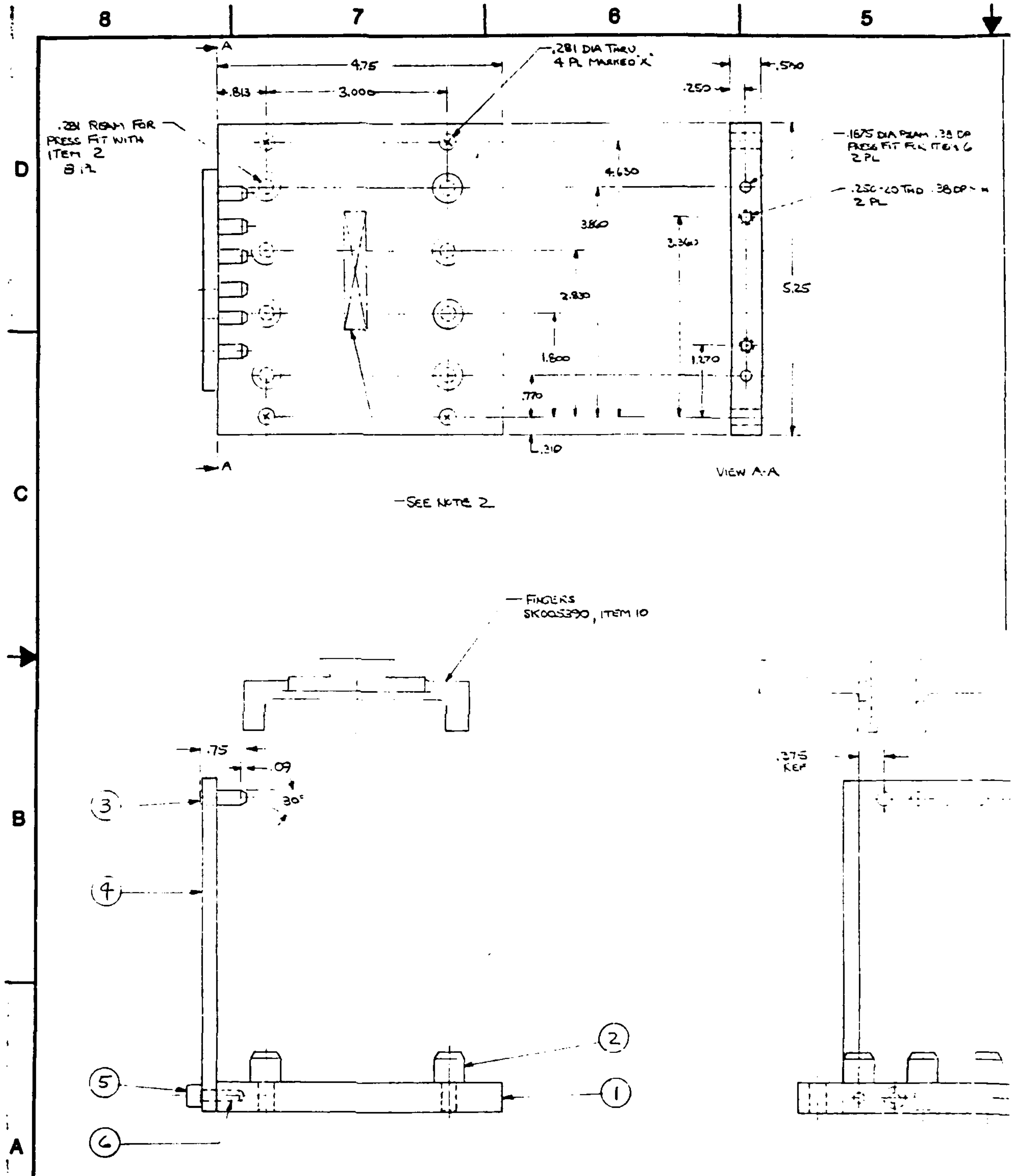
Delco Electronics
GENERAL MOTORS CORPORATION SANTA BARBARA, CALIFORNIA

TITLE: PLATE, BACK - INSEP ASSY

SIZE: F CODE IDENT NO: 13160 DWG NO: DG100034 REV: E

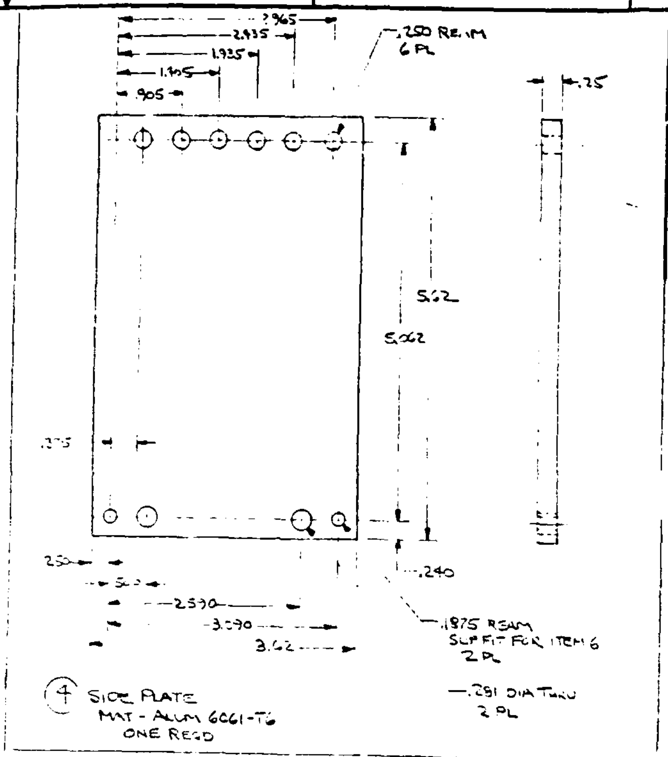
SCALE 1/1 SHEET 1 OF

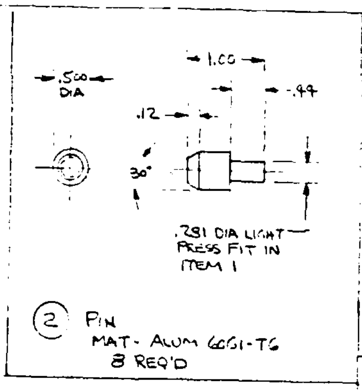
2



NOTES:

1. BREAK ALL SHARP CORNERS .005-.015 RAD OR CHAM.
2. MARK IN LOCATION INDICATED WITH SK005396/DG100034.





REVISIONS					
ZONE	REV	DESCRIPTION	AUTH.	DATE	APPROVED

ITEM	REQD	DESCRIPTION		MATERIAL
6	2	DOWEL	3/16 DIA x 5/8 LG	STEEL
5	2	SOC. HD SCR	1/4-20 x 5/8 LG	STEEL
4	1	SIDE PLATE	1/4 x 3 7/8 x 5 7/8	ALUM 6061-T6
3	6	PIN-DOWEL	1/4 DIA x 3/4 LG	STEEL
2	8	PIN	1/2 DIA x 1 1/4 LG	ALUM 6061-T6
1	1	BASE PLATE	1/2 THK x 5 x 5 1/2	ALUM 6061-T6

THE PART NUMBER IS THE DRAWING NUMBER AND THE DASH NUMBER THAT APPLIES

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES ON
2 PLACE DECIMALS ±.020 | 3 PLACE DECIMALS ±.005 | ANGLES ±1°

MATERIAL

INTERPRET DRAWING PER DOD STD 100

CONTR NO
DFT A. DRECHSLER 12/1985
CHKR
ENGR
APVD
APVD
DSGN ACTIVITY APVD

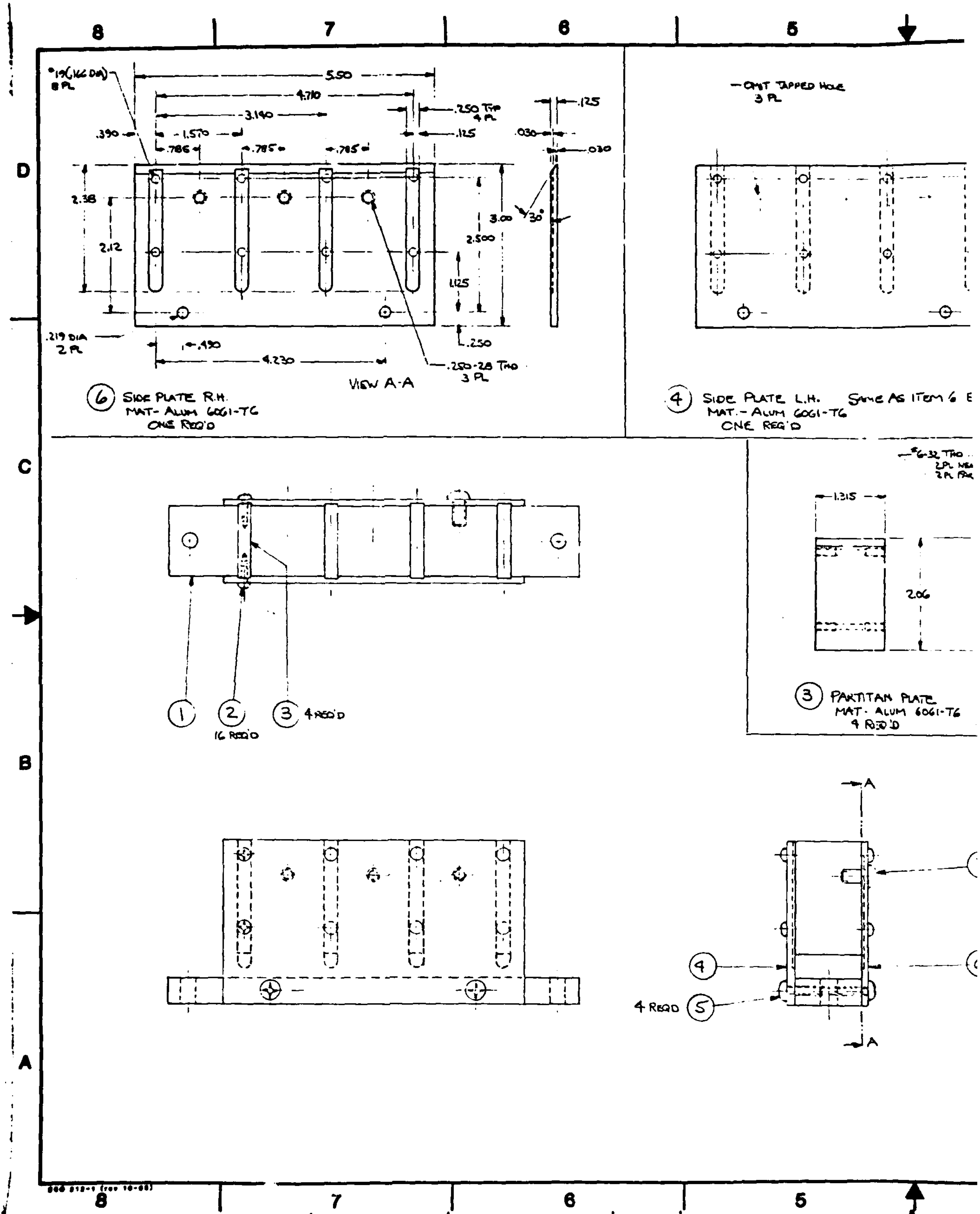
DO NOT SCALE DWG
REF E-41

Delco Systems Operations
GENERAL MOTORS CORPORATION GOLETA CALIFORNIA

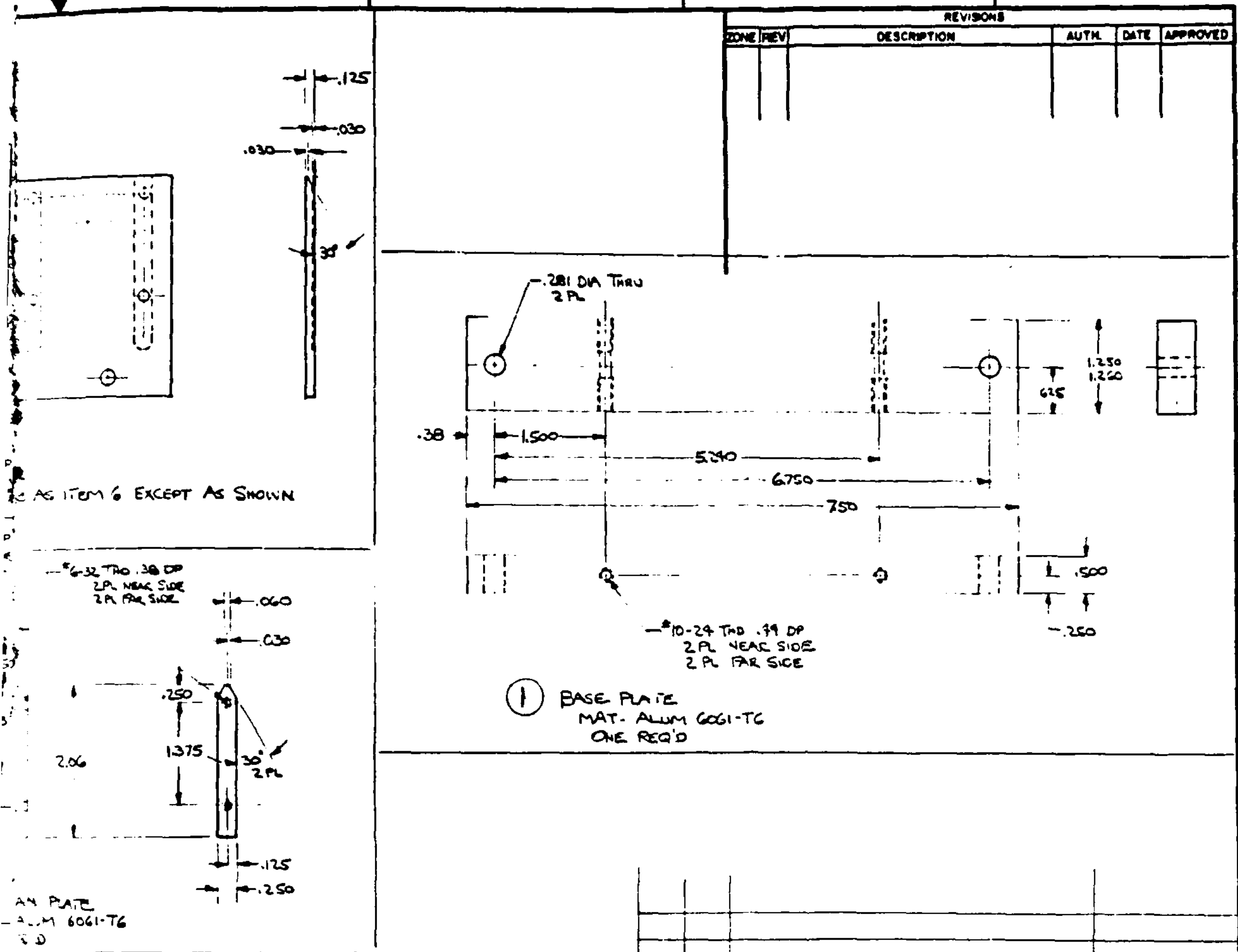
TITLE
PALLET RACK FOR PLATE, BACK
DG100034

SIZE D | FSCM NO 13160 | DWG NO. SKC05396 | REV -

SCALE 1/1 | SHEET | OF 1



SIDE PLATE R.H.
MAT - ALUM 6061-T6
ONE REQ'D
VIEW A-A
.250-28 THD
3 PL
.219 DIA
2 PL
SIDE PLATE L.H. SAME AS ITEM 6
MAT.- ALUM 6061-T6
ONE REQ'D
OMIT TAPPED HOLE
3 PL
PARTITAN PLATE
MAT. ALUM 6061-T6
4 REQ'D
16 REQ'D
4 REQ'D
4 REQD



7 3 REQ'D

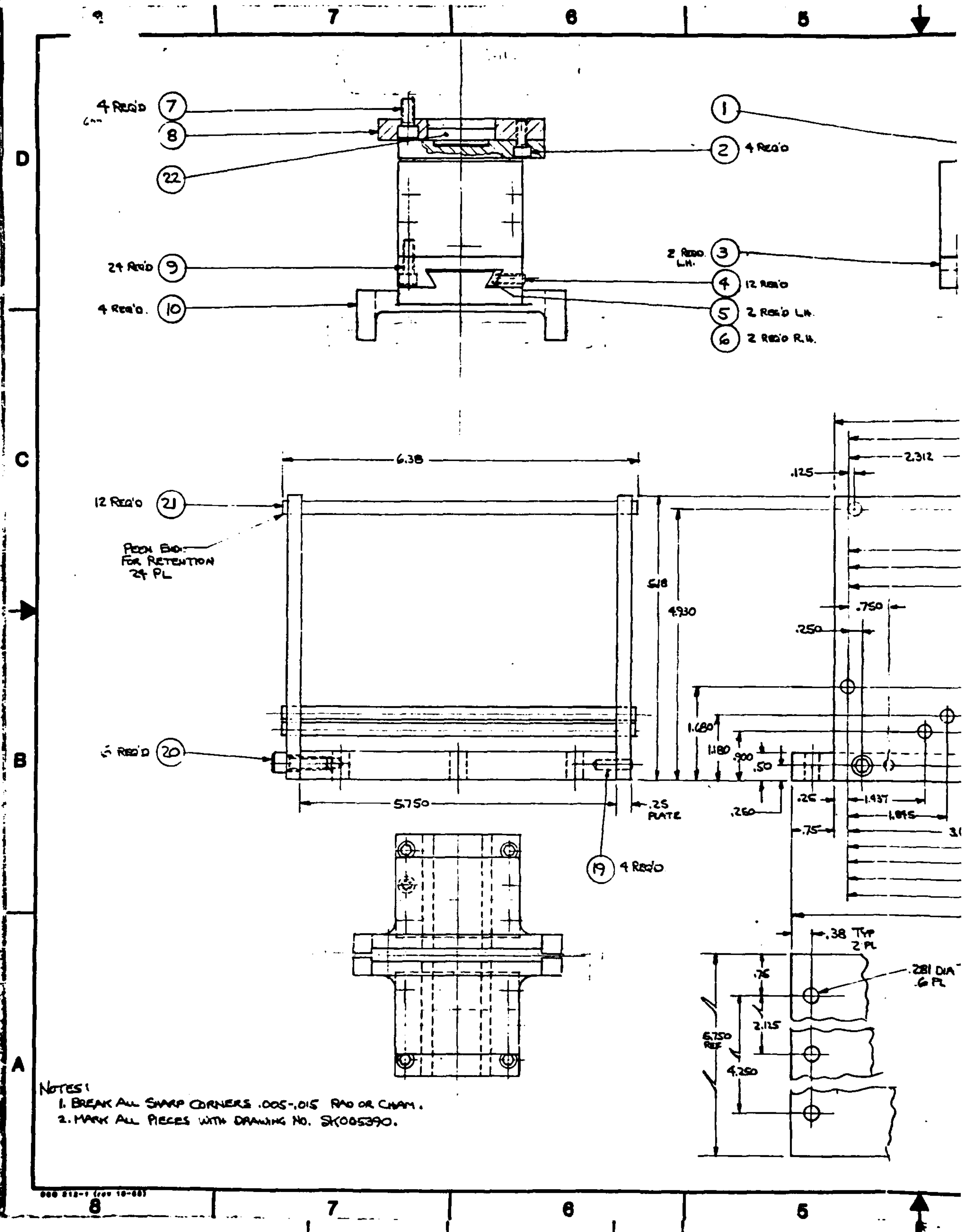
6

ITEM	REQD	DESCRIPTION	MATERIAL
7	3	PAN HD SCR CROSS RECESSED 1/4-20 x 1/2 LG	
6	1	SIDE PLATE R.H. 1/8 x 3 1/4 x 6 3/4	ALUM 6061-T6
5	4	PAN HD SCR CROSS RECESSED #10-24 x 1/2 LG	
4	1	SIDE PLATE L.H. 1/8 x 3 1/4 x 5 3/4	ALUM 6061-T6
3	4	PARTITION PLATE 1/4 x 1 1/2 x 2 1/4	ALUM 6061-T6
2	16	PAN HD SCR CROSS RECESSED #6-32 x 3/8 LG	
1	1	BASE PLATE 1/2 x 1 1/2 x 7 1/2	ALUM 6061-T6

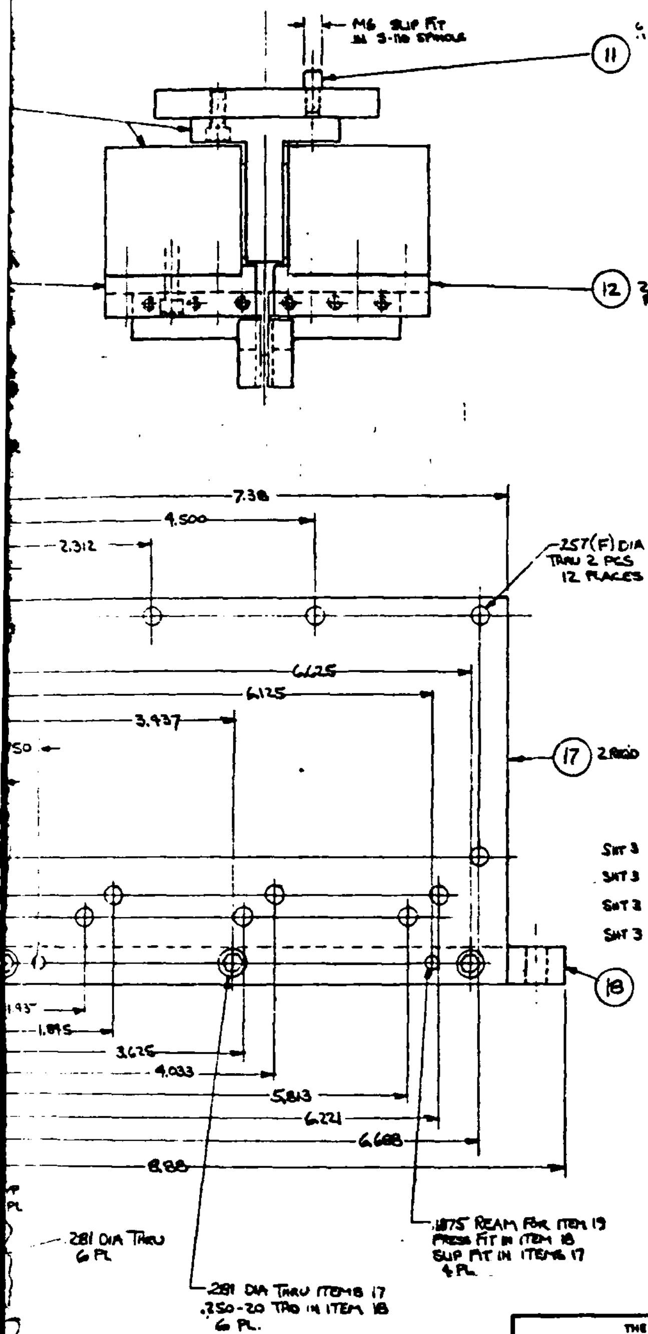
THE PART NUMBER IS THE DRAWING NUMBER AND THE DASH NUMBER THAT APPLIES

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON 2 PLACE DECIMALS ±.010 3 PLACE DECIMALS ±.005 ANGLES ±2°	CONTR NO. DFT A. DRECHSLER 1/4/86 CHKR ENGR APVD APVD APVD APVD DSGN ACTIVITY APVD	**Delco Systems Operations** GENERAL MOTORS CORPORATION GOLETA CALIFORNIA TITLE PALLET RACK FOR BRACKET 7561002
MATERIAL		SIZE D FSCM NO. 13160 DWG NO. SK005397 REV -
INTERPRET DRAWING PER DOD STD-100	DO NOT SCALE DWG REF E-41	SCALE 1:1 SHEET 1 OF 1

2



4 REQ'D 7
8
22
1
2 4 REQ'D
2 REQ'D. LH. 3
24 REQ'D 9
4 12 REQ'D
4 REQ'D. 10
5 2 REQ'D LH.
6 2 REQ'D R.H.
6.38
12 REQ'D 21
PEEN END FOR RETENTION 24 PL
5.18
4.930
2.312
.125
.750
.250
1.680
1.180
.900
.50
REQ'D 20
5.750
.25 PLATE
.260
.25
1.437
1.895
.75
19 4 REQ'D
.38 TYP 2 PL
.281 DIA .6 PL
.76
2.125
6.750 REF
4.250
NOTES:
1. BREAK ALL SHARP CORNERS .005-.015 RAD OR CHAM.
2. MARK ALL PIECES WITH DRAWING NO. SK005390.



REVISIONS					
ZONE	REV	DESCRIPTION	AUTH.	DATE	APPROVED
-	A	REVISED SHEETS 1, 2, 3, 4 ADDED ITEM 22 ON SHTS 1 & 2	A.C.D.	2/10/86	

ITEM	REQ'D	DESCRIPTION	MATERIAL
33		SEE SHEET 4 FOR ITEMS 26 THRU 33	
26			
25			
24			
23			
22	1	CENTERING PLUG 1½ DIA x ½ LG.	ALUM-6061-T6
21	12	ROD ¼ DIA x 6⅜ LG	ALUM OR STEEL
20	6	SOC HD SCR ¼-20 x ¾ LG	
19	4	DOWEL PIN 3/16 DIA x ⅝ LG	STEEL
18	1	BASE PLATE ½ THICK x 6 x 9⅛	ALUM 6061-T6
17	2	SIDE PLATE ¼ THICK x 5½ x 7½	ALUM 6061-T6
16	1	PIN 5/32 DIA x 3⅛ LG	DRILL ROD
15	1	HOLLESS SOC SET SCREW #8-32 x ⅜ LG	
14	1	FINGER 1¼ x 2 x 2½	ALUM 6061-T6
13	3	FINGER 1¼ x 2 x 2½	ALUM 6061-T6
12	2	DOVE TAIL BLOCK R.H. ¾ x 2¼ x 2½	STEEL 1020
11	1	DOWEL PIN ¼ DIA x 1" LG	DRILL ROD
10	4	FINGER 1¼ x 2¼ x 4	ALUM 6061-T6
9	24	SOC. HD SCR #10-24 x ⅝ LG	
8	1	ADAPTER 3¼ DIA x ½ LG	ALUM-6061-T6
7	4	SOC HD SCR M6x1 x 14 MM LG	
6	2	GIB R.H. ⅛ x ½ x 2¼	STEEL C.R.
5	2	GIB L.H. ⅛ x ½ x 2¼	STEEL C.R.
4	12	HOLLESS SOC SET SCR. #10-32 x ½ LG	
3	2	DOVE TAIL BLOCK L.H. ¾ x 2¼ x 2½	STEEL 1020
2	4	SOC HD SCR #10-24 x ½ LG	
1	1	PARALLEL GRIPPER MECANOTRON FLAT-PG-294	PURCH (SEE SHT 4)

(SHT 3 noted beside items 16, 15, 14, 13)

THE PART NUMBER IS THE DRAWING NUMBER AND THE DASH NUMBER THAT APPLIES

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES

TOLERANCES ON

2 PLACE DECIMALS	3 PLACE DECIMALS	ANGLES
±.010	±.005	±½°

MATERIAL

INTERPRET DRAWING PER DOD-STD-100

CONTR NO.		
DFT	A. DRECHSLER	12/16/85
CHKR		
ENGR		
APVD		APVD
APVD		APVD
DSGN ACTIVITY APVD		

DO NOT SCALE DWG — REF E-41

Delco Systems Operations
GENERAL MOTORS CORPORATION — GOLETA, CALIFORNIA

TITLE: TOOLING FOR S-110 ROBOT INCLUDES FINGERS FOR 4th AXIS PALLET RACK FOR FRONT PANEL 7565016 MECANOTRON GRIPPER MOD.

SIZE	FSCM NO.	DWG NO.	REV
D	13160	SK005390	A

SCALE — SHEET 1 OF 4

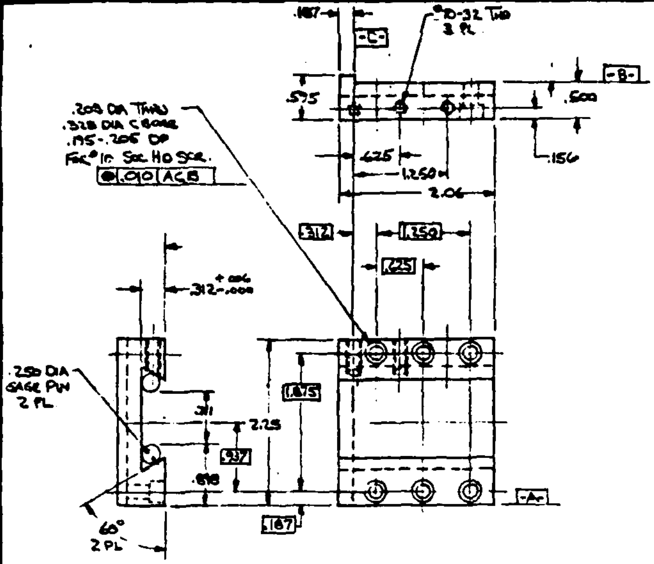
SHEET	1	2	3	4
REV	A	A	A	A

1

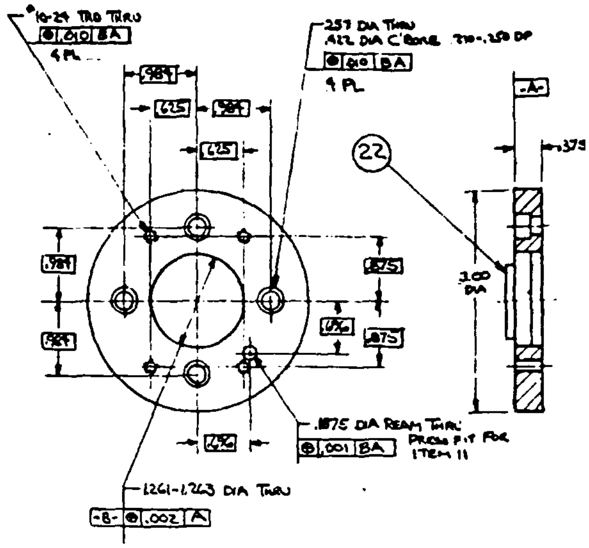
2

8 7 6 5

D

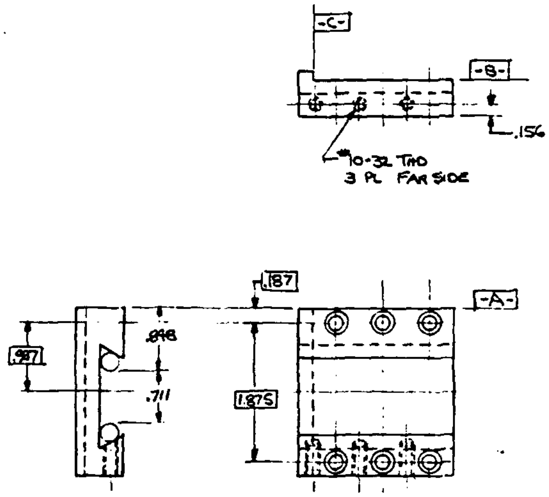


(12) DOVE TAIL BLOCK - RIGHT HAND
MAT - 1020 STEEL
2 REQ'D.

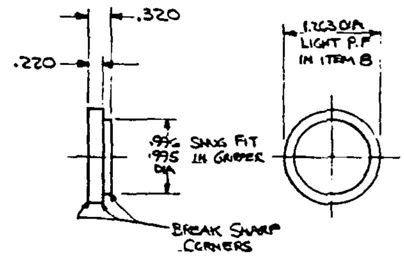


C

(8) ADAPTER S-110 TO MECANCTRON GRIPPER
MAT - ALUM 6061-T6
ONE REQ'D



(3) DOVE TAIL BLOCK - LEFT HAND
SAME AS ITEM EXCEPT OPPOSITE
HAND AS SHOWN
2 REQ'D



(22) CENTERING PLUG
MAT - ALUM 6061-T6
ONE REQ'D.

B

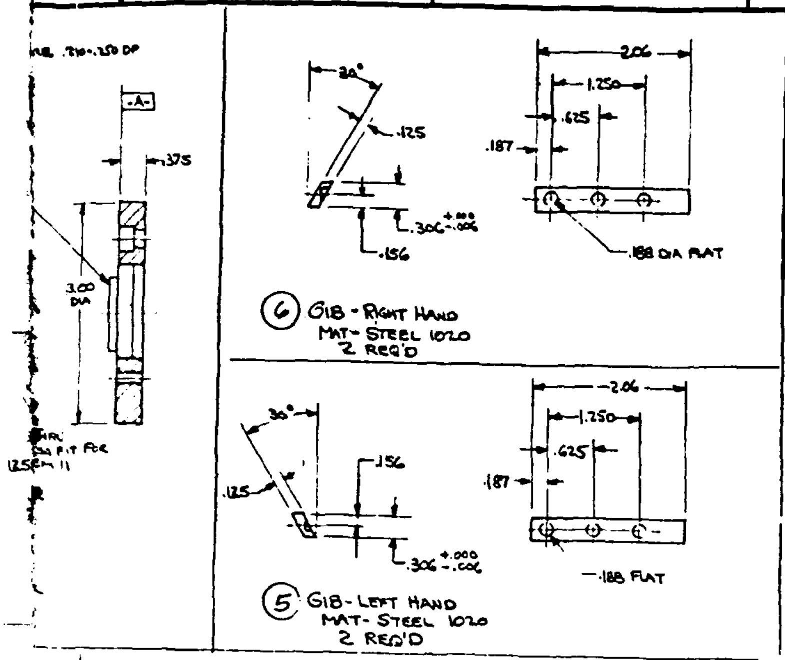
A

8 7 6 5

4 3 2 1

REVISIONS

ZONE	REV	DESCRIPTION	AUTH.	DATE	APPROVED



D C B A

THE PART NUMBER IS THE DRAWING NUMBER AND THE DASH NUMBER THAT APPLIES

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES ON
2 PLACE DECIMALS ±.010
3 PLACE DECIMALS ±.005
ANGLES ±1/4°

MATERIAL

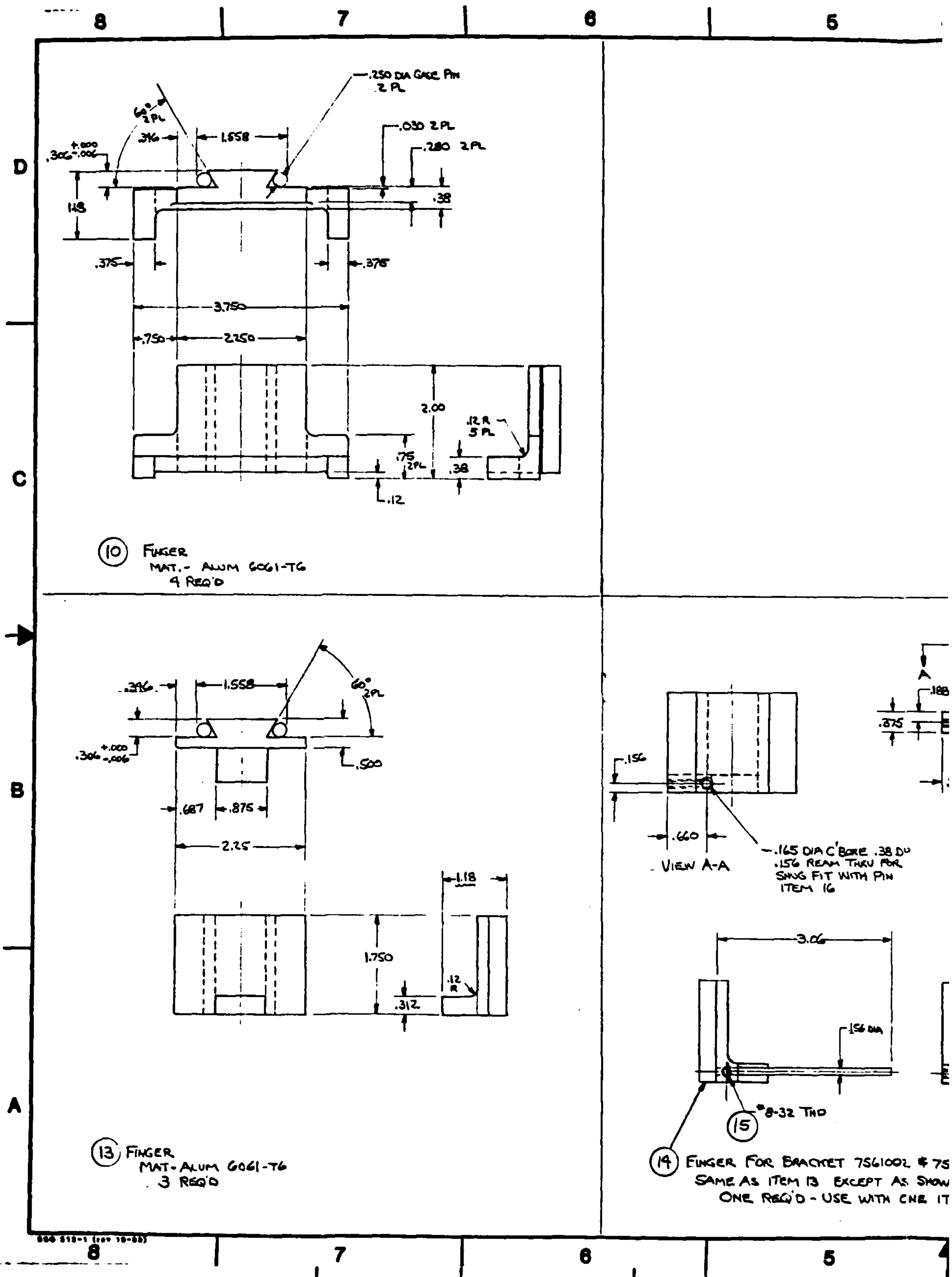
INTERPRET DRAWING PER DOD-STD-100

CONTR. NO.
DFTR A. Drechsler 7/10/85
CHKR
ENGR
APVD APVD
APVD APVD
DSGN ACTIVITY APVD
DO NOT SCALE DWG
REF E-41

Delco Systems Operations
GENERAL MOTORS CORPORATION GOLETA, CALIFORNIA
TITLE

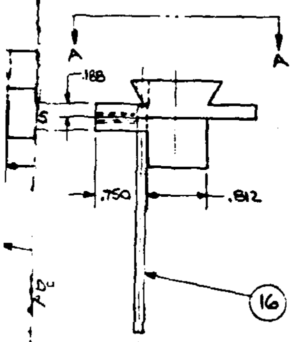
SIZE D | FSCM NO. 13160 | DWG NO. SK005390 | REV. A
SCALE | SHEET 2 OF 4

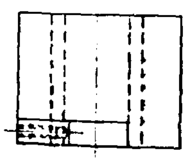
4 3 2 1

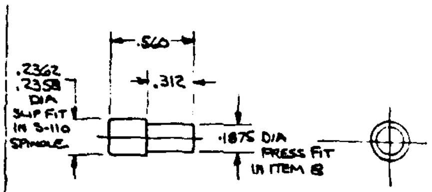


8
7
6
5
D
C
B
A
.250 DIA GAGE PIN
2 PL
60°
2 PL
.396
1.558
.306 +.000 -.006
1.18
.030 2 PL
.280 2 PL
.38
.375
.375
3.750
.750
2.250
2.00
.12 R
5 PL
.75
2 PL
.38
.12
(10) FINGER
MAT.- ALUM 6061-T6
4 REQ'D
.396
1.558
60°
2 PL
.306 +.000 -.006
.500
.687
.875
2.25
1.18
1.750
.12 R
.312
(13) FINGER
MAT - ALUM 6061-T6
3 REQ'D
A
.188
.375
.156
.660
VIEW A-A
.165 DIA C'BORE .38 D
.156 REAM THRU FOR
SNUG FIT WITH PIN
ITEM 16
3.06
.156 DIA
#8-32 THD
(15)
(14) FINGER FOR BRACKET 7561002 # 75
SAME AS ITEM 13 EXCEPT AS SHOW
ONE REQ'D - USE WITH ONE IT
8
7
6
5

ZONE	REV	REVISIONS DESCRIPTION	AUTH.	DATE	APPROVED





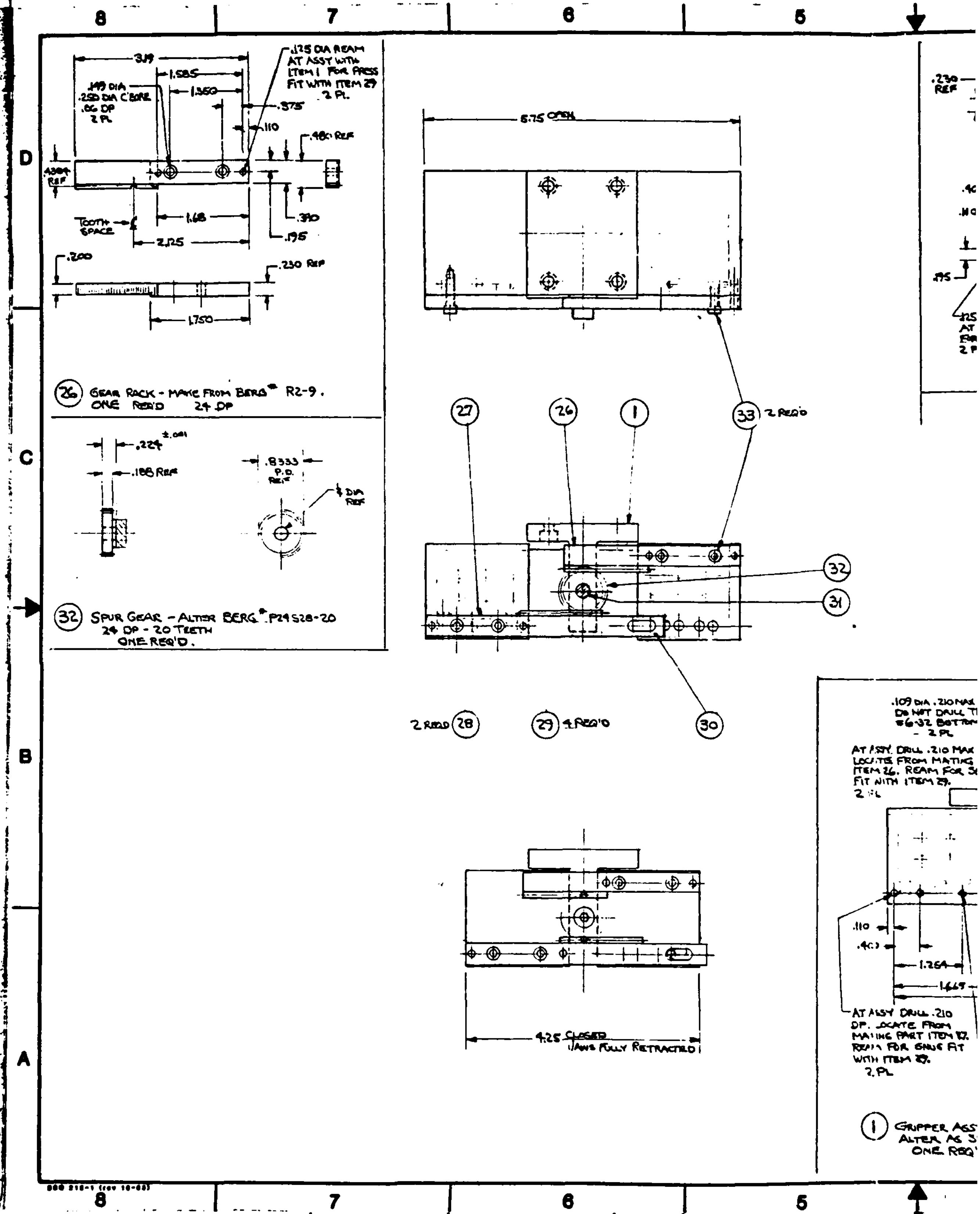


(11) STEPPED DOWEL
MAT- DRILL ROD
ONE REQ'D.

...O. # 7567084
AS SHOWN
ONE ITEM 13

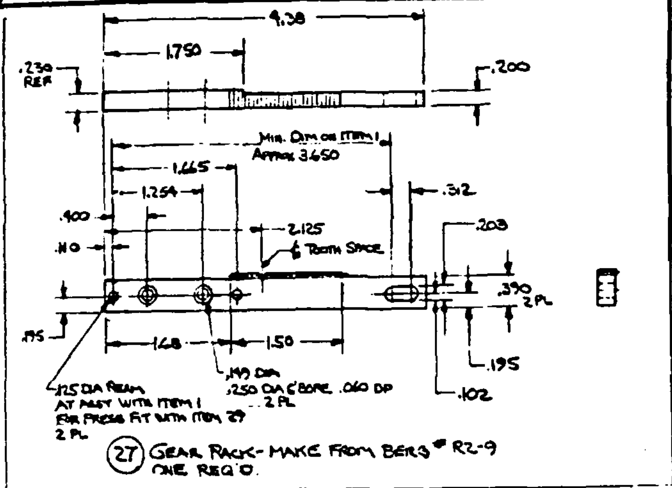
THE PART NUMBER IS THE DRAWING NUMBER AND THE DASH NUMBER THAT APPLIES

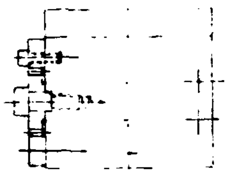
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ON: 2 PLACE DECIMALS ±.010; 3 PLACE DECIMALS ±.005; ANGLES ±1/2°	CONTR NO. / DFT A. DRECHSLER 11/1/85 / CHKR / ENGR / APVD / APVD / APVD / APVD / DSGN ACTIVITY APVD	Delco Systems Operations, GENERAL MOTORS CORPORATION, GOLETA, CALIFORNIA / TITLE
MATERIAL		SIZE D · FSCM NO. 13160 · DWG NO. SK005390 · REV A
INTERPRET DRAWING PER DOD-STD-100	DO NOT SCALE DWG · REF E-41	SCALE · SHEET 3 OF 4

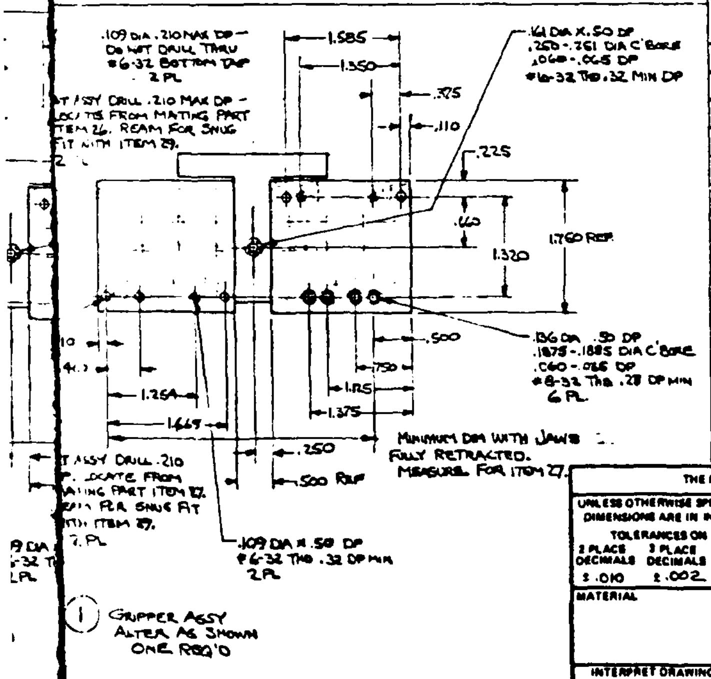


8
7
6
5
D
C
B
A
.125 DIA REAM AT ASSY WITH ITEM 1 FOR PRESS FIT WITH ITEM 29 2 PL.
.149 DIA .250 DIA C'BORE .06 DP 2 PL
TOOTH SPACE
26 GEAR RACK - MAKE FROM BERG R2-9. ONE REQ'D 24 DP
32 SPUR GEAR - ALTER BERG P24S28-20 24 DP - 20 TEETH ONE REQ'D.
5.75 OPEN
33 2 REQ'D
2 REQ'D 28
29 4 REQ'D
4.25 CLOSED JAWS FULLY RETRACTED
AT ASSY DRILL .210 DP. LOCATE FROM MATING PART ITEM 27. REAM FOR SNUG FIT WITH ITEM 29. 2 PL.
1 GRIPPER ASS ALTER AS ONE REQ'

REVISIONS					
ZONE	REV	DESCRIPTION	AUTH.	DATE	APPROVED







ITEM	REQ'D	DESCRIPTION	MATERIAL
33	2	SOC HD SCR #6-32 x 3/8 LG	
32	1	SPUR GEAR BERG #P24S28-20 (24 DP, 20 TEETH)	PURCH
31	1	SHOULDER SCREW BERG # PR-20 (#10-32 THD X .2495 BODY X .313 LG)	
30	1	SHOULDER SCREW BERG # PR-9 (8/32 THD X .187 BODY X .313 LG)	
29	4	DOWEL 1/8 DIA x 7/16 LG	
28	2	SOCK HD SCR #6-32 x 1/2 LG	
27	1	GEAR RACK BERG # R2-9 4 1/2 LG	PURCH
26	1	GEAR RACK BERG # R2-9 3 3/8 LG	PURCH
1	1	GRIPPER MECAMOTRON FLAT- FS-294	PURCH

THE PART NUMBER IS THE DRAWING NUMBER AND THE DASH NUMBER THAT APPLIES

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES ON
2 PLACE DECIMALS ±.010 | 3 PLACE DECIMALS ±.002 | ANGLES ±

MATERIAL

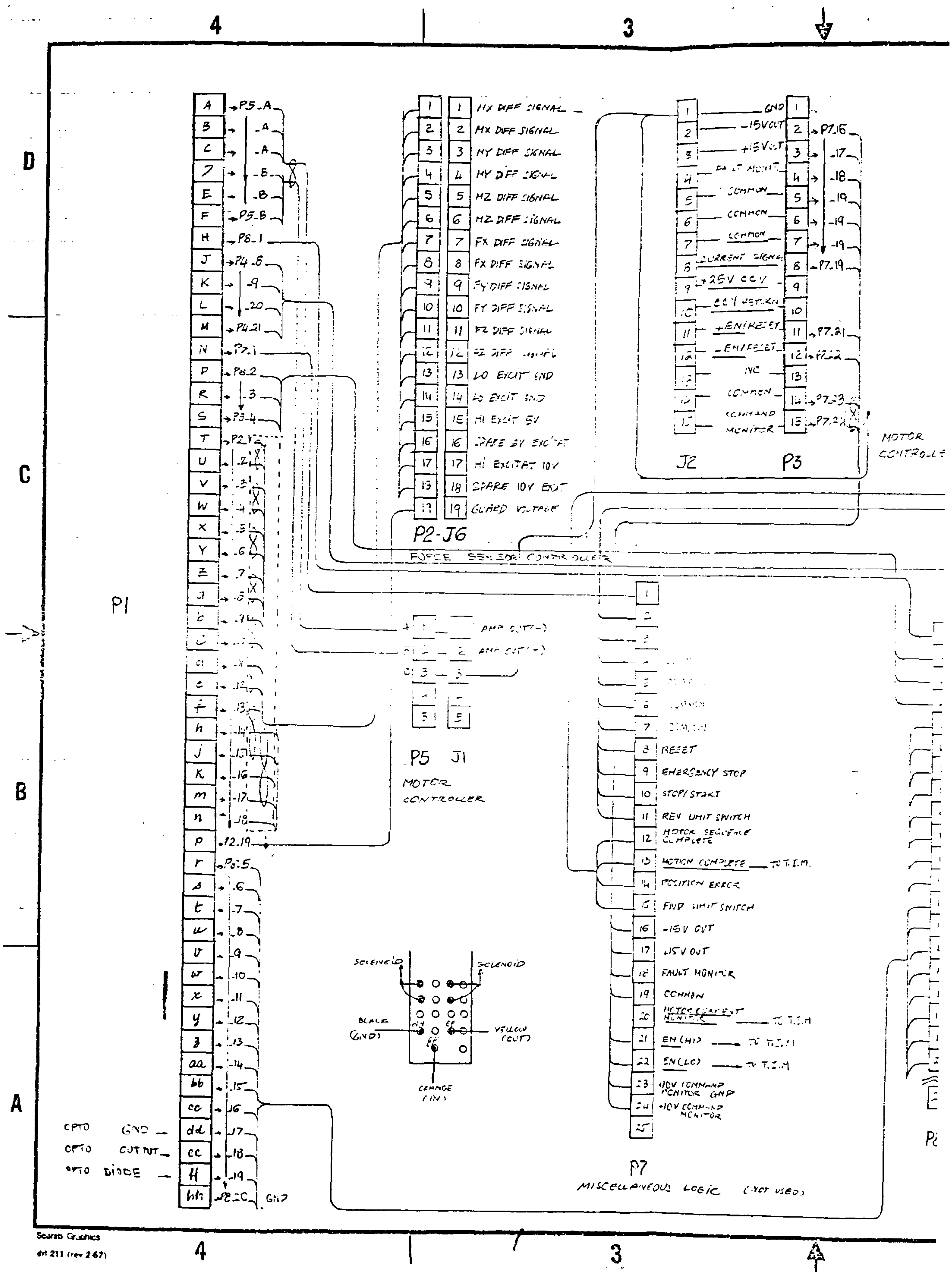
CONTR. NO.
DFT A. DRECHSLER 12/9/86
CHKR
ENGR
APVD | APVD
APVD | APVD
DSGN ACTIVITY APVD

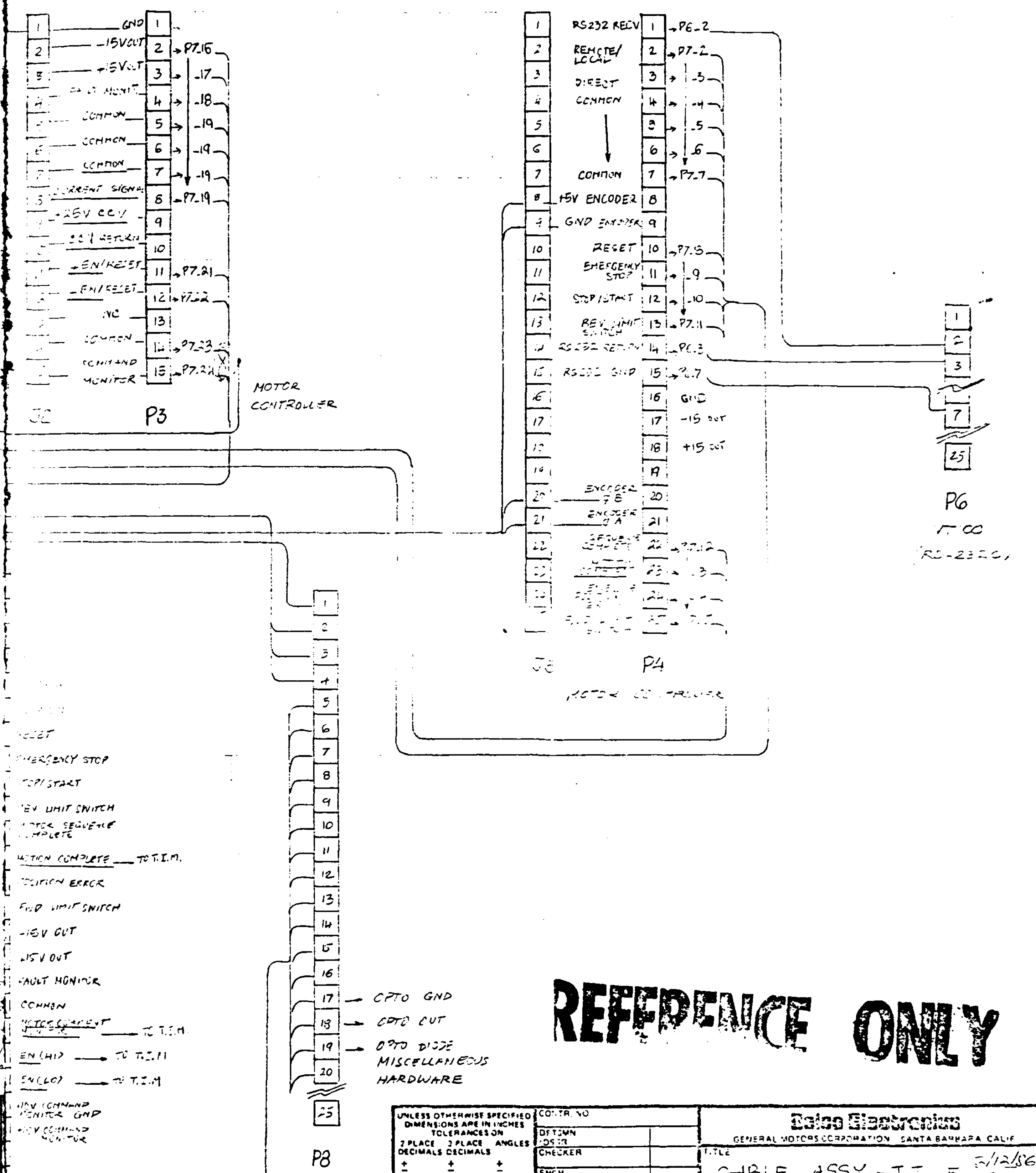
Delco Systems Operations
GENERAL MOTORS CORPORATION — GOLETA, CALIFORNIA

TITLE
MECAMOTRON GRIPPER
SELF CENTERING MECHANISM

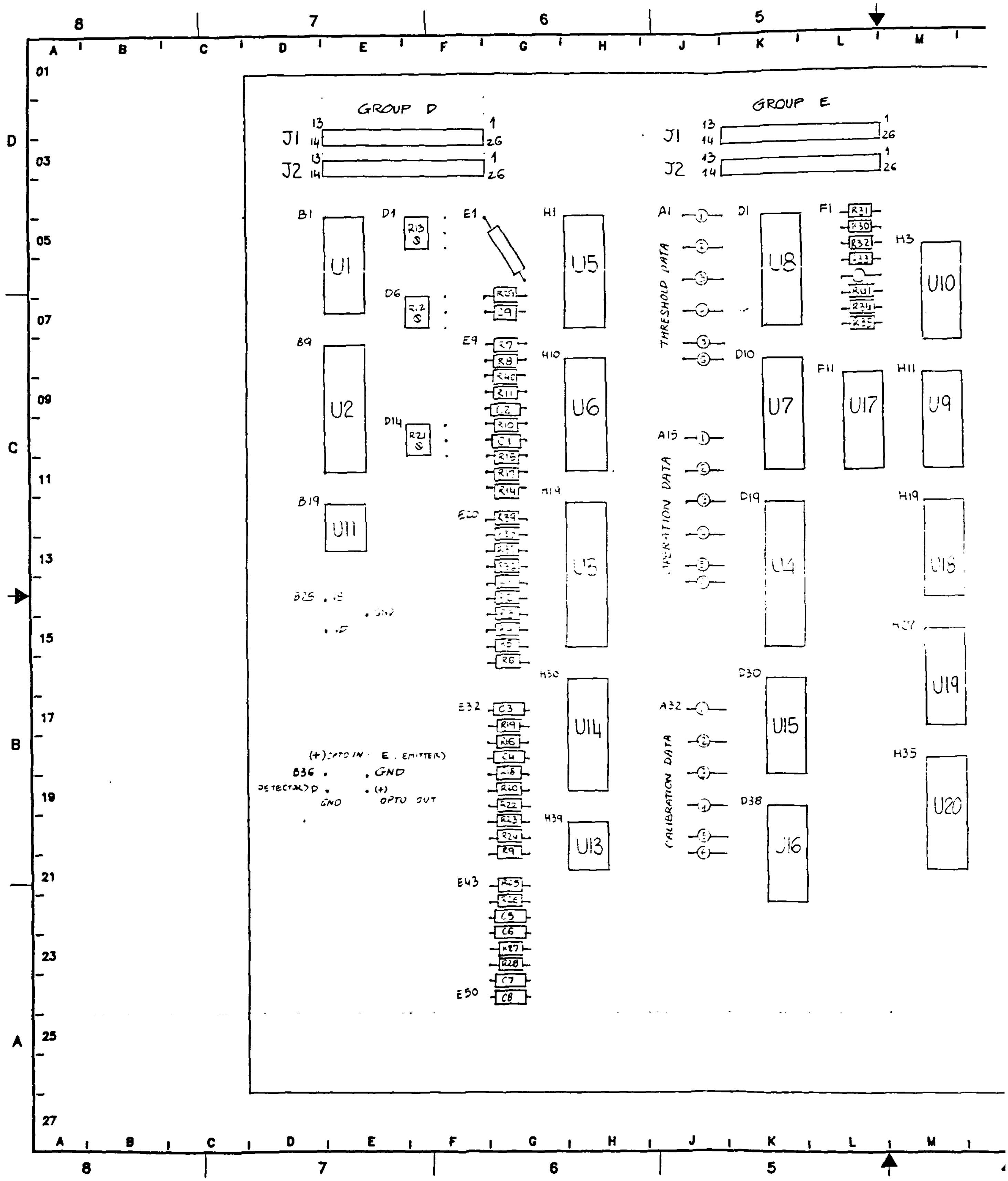
SIZE D | FSCM NO. 13160 | DWG NO. SK005390 | REV A

INTERPRET DRAWING PER DOD-STD-100 | DO NOT SCALE DWG | REF E-41 | SCALE 1"=1" | SHEET 4 OF 4

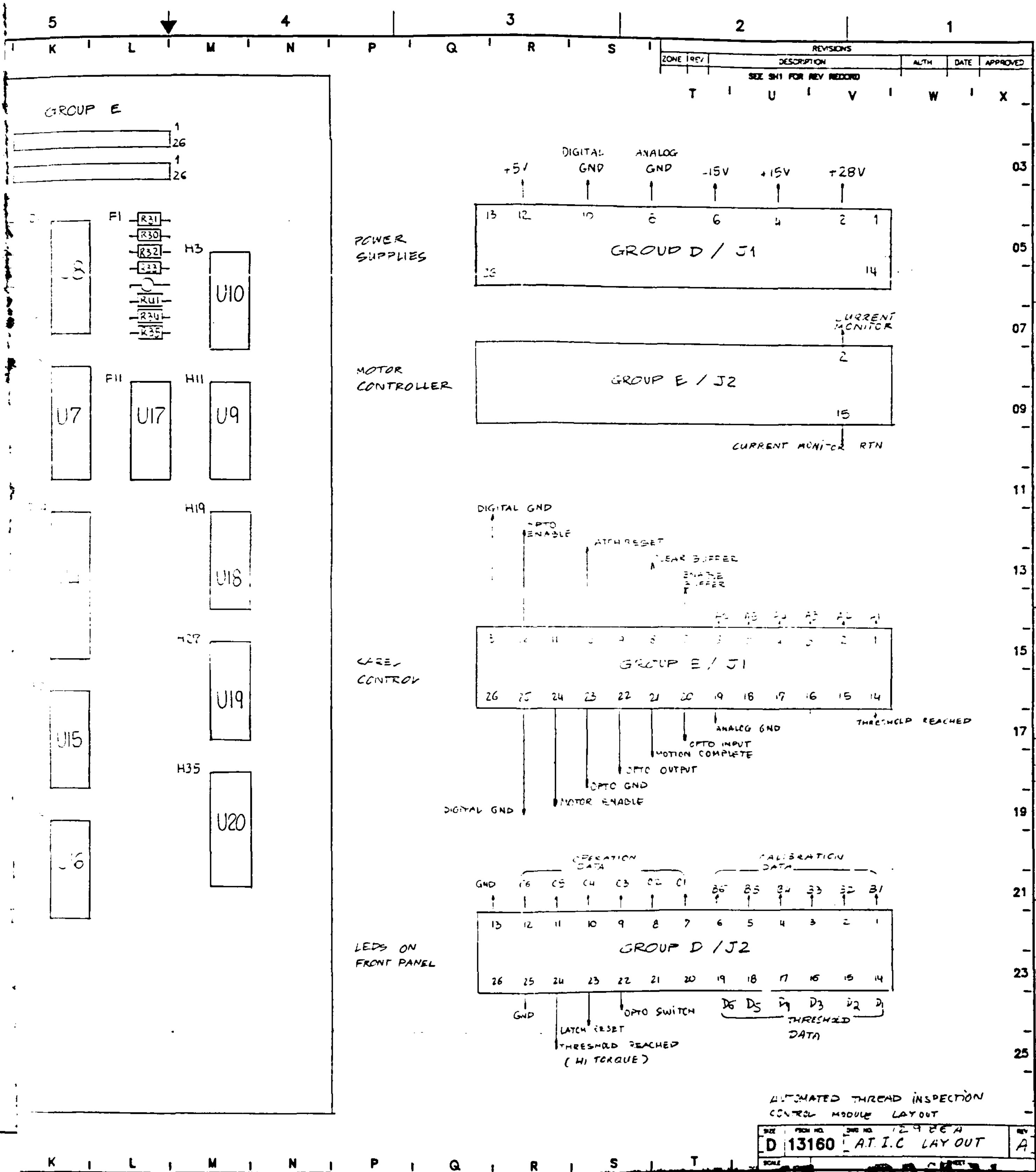

P1
P2-J6
FORCE SENSOR CONTROLLER
J2
P3
MOTOR CONTROLLER
P5 J1
MOTOR CONTROLLER
P7
MISCELLANEOUS LOGIC (NOT USED)
MX DIFF SIGNAL
MY DIFF SIGNAL
MZ DIFF SIGNAL
FX DIFF SIGNAL
FY DIFF SIGNAL
FZ DIFF SIGNAL
LO EXCIT GND
HI EXCIT 5V
SPARE 5V EXCIT
HI EXCITAT 10V
SPARE 10V EXCIT
GUARD VOLTAGE
GND
-15V OUT
+15V OUT
FAULT MONIT
COMMON
CURRENT SIGNAL
+25V CCV
CCV RETURN
+EN/RESET
-EN/RESET
NC
COMMAND MONITOR
AMP OUT (-)
AMP OUT (+)
RESET
EMERGENCY STOP
STOP/START
REV LIMIT SWITCH
MOTOR SEQUENCE COMPLETE
MOTION COMPLETE — TO T.I.M.
POSITION ERROR
FWD LIMIT SWITCH
-15V OUT
+15V OUT
FAULT MONITOR
COMMON
MOTOR CURRENT MONITOR — TO T.I.M.
EN (HI) — TO T.I.M.
EN (LO) — TO T.I.M.
+10V COMMAND MONITOR GND
+10V COMMAND MONITOR
SOLENOID
SOLENOID
BLACK (GND)
YELLOW (OUT)
ORANGE (IN)
OPTO GND
OPTO OUTPUT
OPTO DIODE
GND
D
C
B
A
4
3



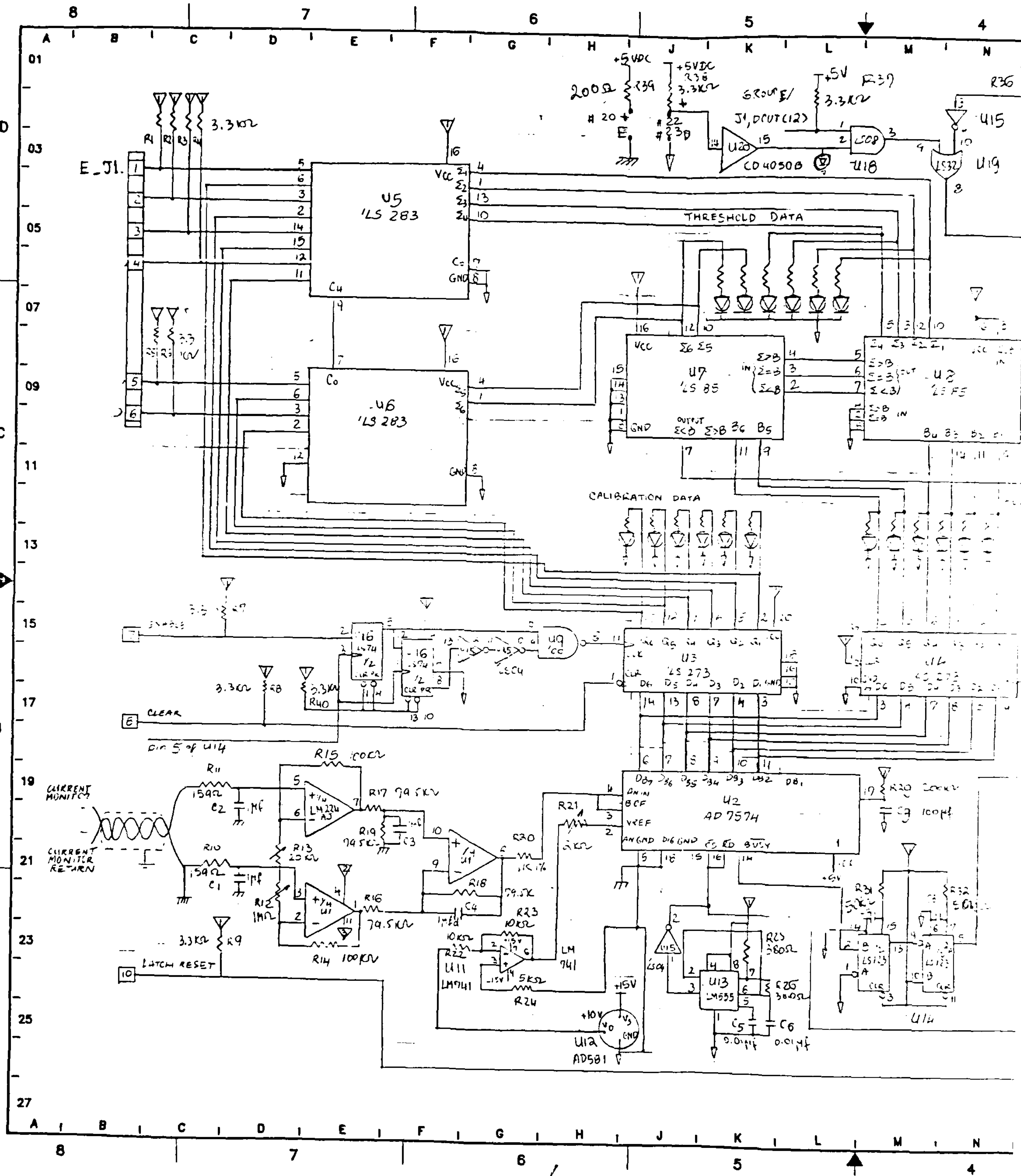
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON 2 PLACE DECIMALS ± 3 PLACE DECIMALS ± ANGLES ±	CONTR NO	Delco Electronics GENERAL MOTORS CORPORATION SANTA BARBARA CALIF
MATERIAL	DFTSMN / DSGN / CHECKER / ENGR / APPD / APPD	TITLE CABLE ASSY - T.I. - E... 5/12/86 1/25/87
	DSGN ACTIVITY APPD	SIZE — CODE IDENT NO. 13160 — DWG NO. 12387 — REV B
REF (AC-DHL) — CHG CONTROL	OTHER APPROVAL	SCALE — WEIGHT — SHEET 1 OF 1



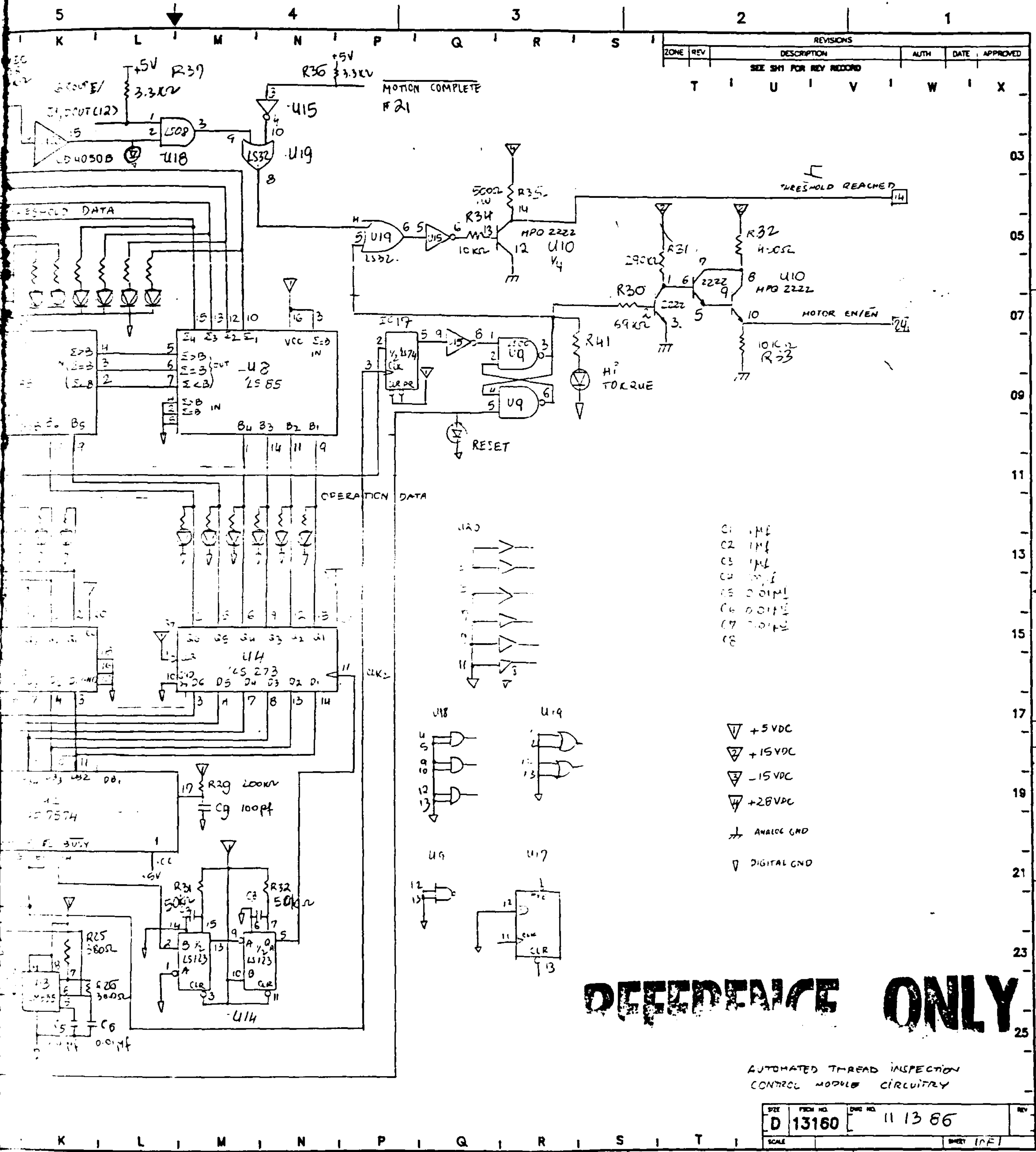
GROUP D
GROUP E
J1
J2
B1
D1
E1
H1
A1
F1
H3
U1
U5
U8
U10
THRESHOLD DATA
D6
B9
E9
H10
D10
F11
H11
U2
U6
U7
U17
U9
D14
A15
OPERATION DATA
B19
H19
D19
U11
U3
U4
U18
E20
B25
H30
D30
U14
U15
U19
E32
A32
CALIBRATION DATA
(+) OPTO IN
E. EMITTER)
B36
GND
DETECTOR) D
(+)
OPTO OUT
H35
U20
H39
D38
U13
U16
E43
E50
R13
R12
R21
R31
R30
R32
C1
C2
C3
C4
C5
C6
C7
C8
R6
R7
R8
R9
R10
R11
R14
R15
R16
R17
R19
R20
R22
R23
R24
R27
R28
R40



REFERENCE ONLY

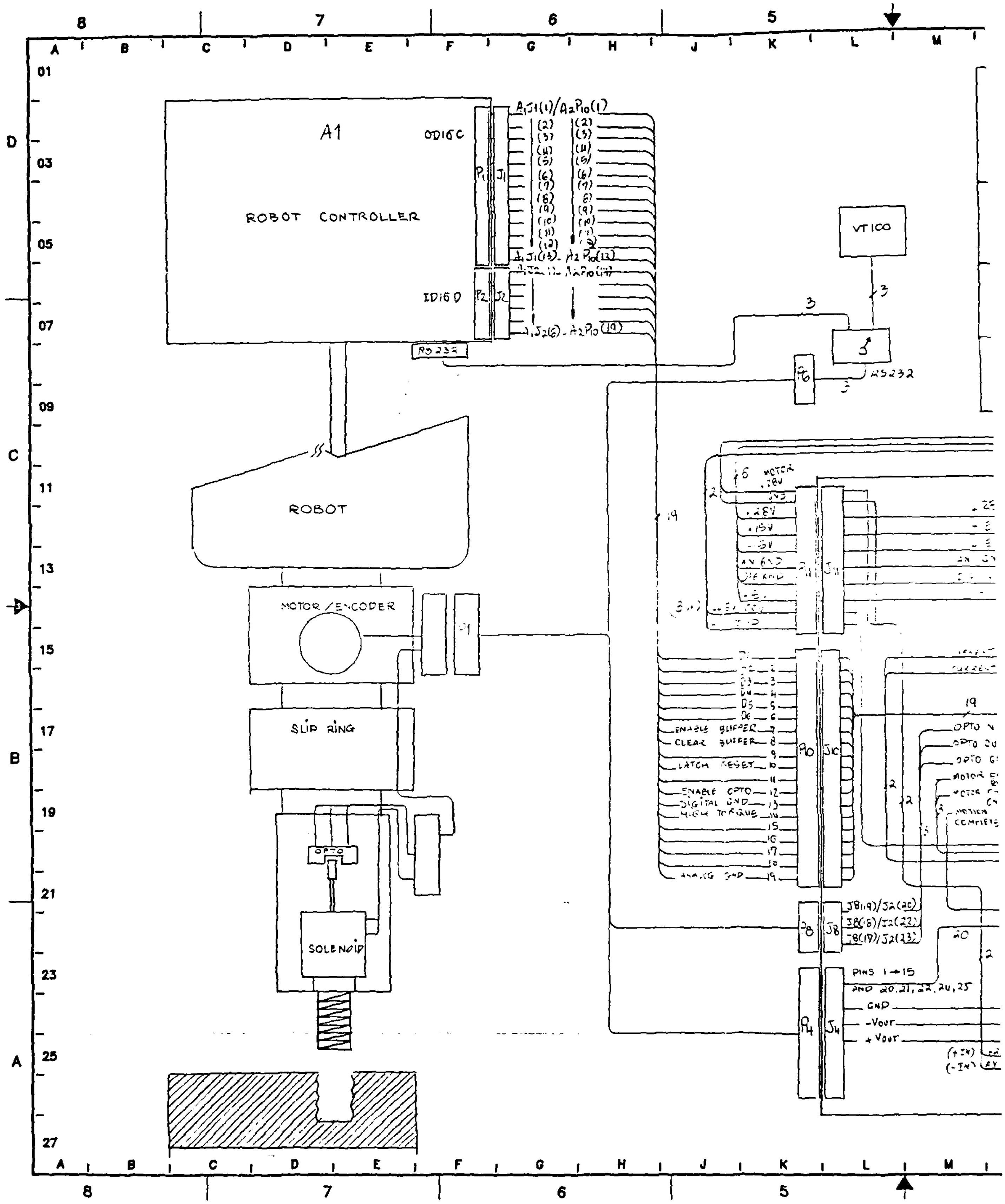


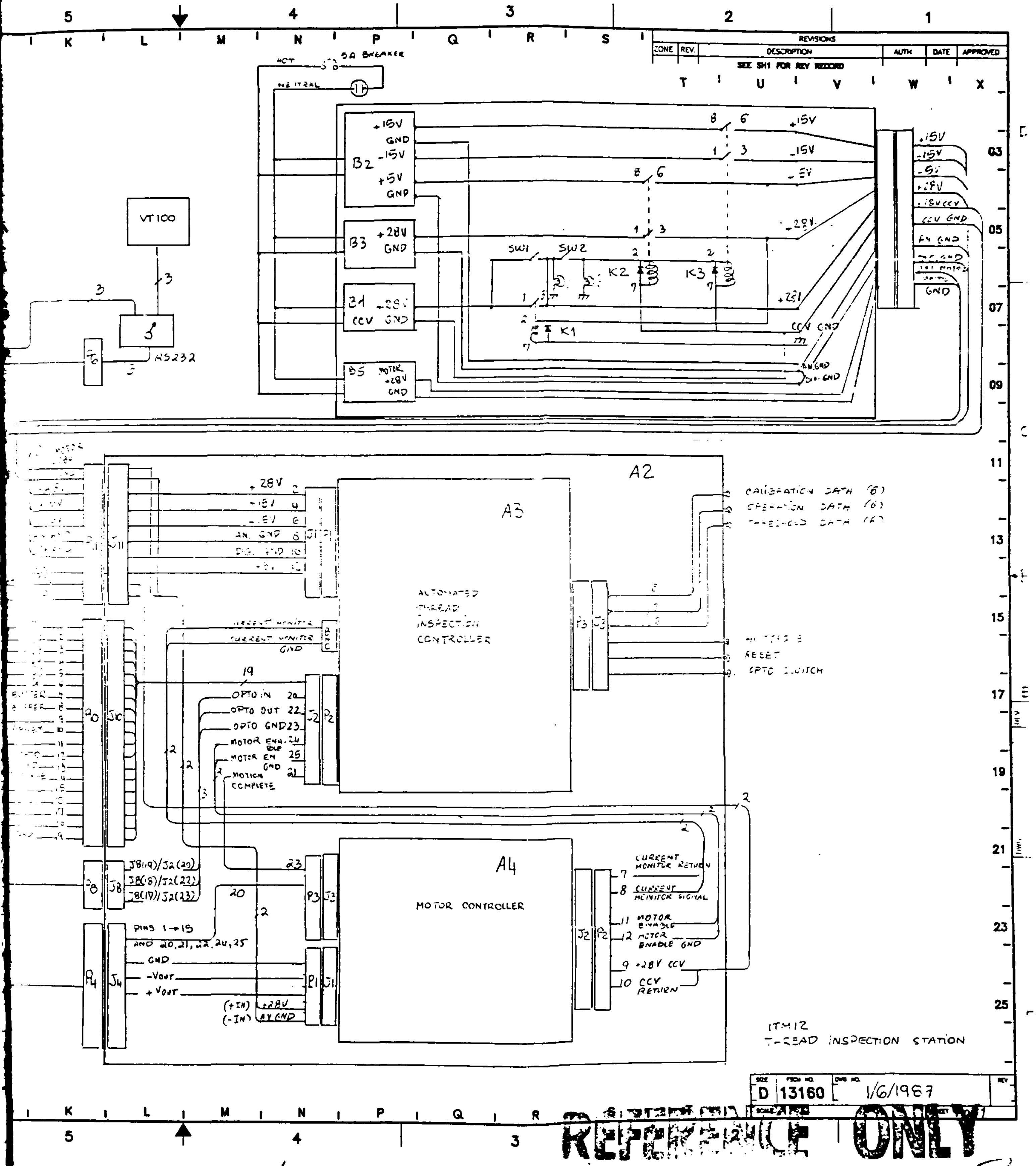
E_J1
U5
'LS 283
U6
'LS 283
U7
'LS 85
U8
'LS 85
U3
'LS 273
U2
AD 7574
U20
CD 4050B
U18
U19
U15
U13
LM555
U11
LM741
U12
AD581
U14
THRESHOLD DATA
CALIBRATION DATA
CLEAR
LATCH RESET
CURRENT MONITOR
CURRENT MONITOR RETURN
ENABLE
+5VDC
+5V
+15V
+10V
R15 100KΩ
R17 79.5KΩ
R19 79.5KΩ
R16 79.5KΩ
R14 100KΩ
R18 79.5K
R13 20KΩ
R12 1MΩ
R11 159Ω
R10 159Ω
R9 3.3KΩ
R8 3.3KΩ
R40 3.3KΩ
R23 10KΩ
R22 10KΩ
R24 5KΩ
R25 360Ω
R26 360Ω
R29 100KΩ
C9 100pf
C5 0.01μf
C6 0.01μf
LM324
LM741
DIP 5 OF U14



REVISIONS
ZONE
REV
DESCRIPTION
AUTH
DATE
APPROVED
SEE SH1 FOR REV RECORD
+5V
R37
3.3KΩ
R36
3.3KΩ
MOTION COMPLETE
F21
U15
U18
U19
LS08
LS32
CD4050B
THRESHOLD REACHED
14
500Ω
R35
R34
10KΩ
HPQ 2222
U10
R31
R32
R30
290KΩ
69KΩ
HPQ 2222
MOTOR EN/EN
24
10KΩ
R33
R41
HI TORQUE
RESET
U9
IC17
1/2 LS74
U8
LS 85
OPERATION DATA
U4
LS 273
CLK
R29
200KΩ
C9
100pf
R31
50KΩ
R32
50KΩ
LS123
U14
R25
380Ω
R26
380Ω
C6
0.01μf
C1 1μf
C2 1μf
C3 1μf
C5 0.01μf
C6 0.01μf
+5 VDC
+15 VDC
-15 VDC
+28 VDC
ANALOG GND
DIGITAL GND
REFERENCE ONLY
AUTOMATED THREAD INSPECTION CONTROL MODULE CIRCUITRY
D
13160
11 13 86

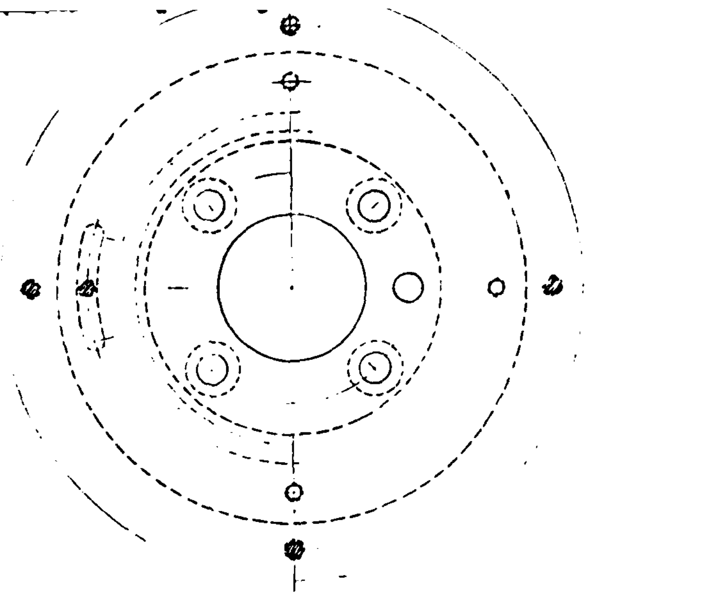
1218861

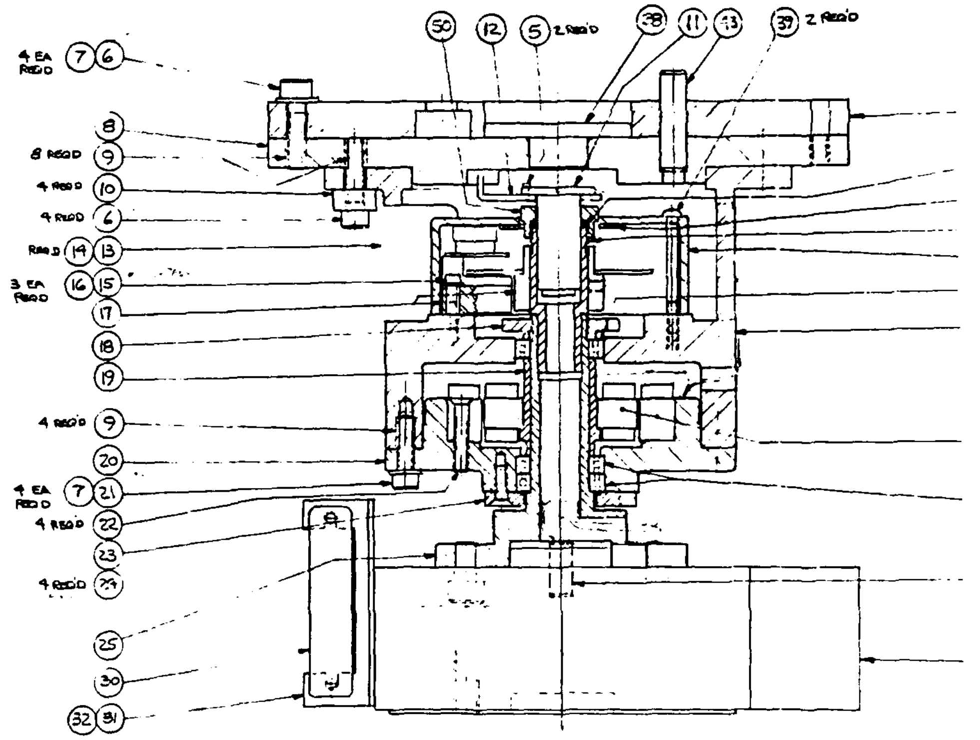

A1
ROBOT CONTROLLER
OD16C
ID16D
P1
J1
P2
J2
RS232
VT100
ROBOT
MOTOR / ENCODER
SLIP RING
OPTO
SOLENOID
ENABLE BUFFER
CLEAR BUFFER
LATCH RESET
ENABLE OPTO
DIGITAL GND
HIGH TORQUE
ANALOG GND
P10
J10
P8
J8
P4
J4
PINS 1→15
GND
-Vout
+Vout

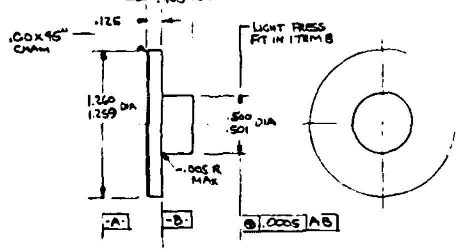


REVISIONS
ZONE
REV.
DESCRIPTION
AUTH
DATE
APPROVED
SEE SH1 FOR REV RECORD
HOT
5A BREAKER
NEUTRAL
B2
+15V
GND
-15V
+5V
GND
B3
+28V
GND
B1
+28V
CCV GND
B5
MOTOR +28V
GND
SW1
SW2
K1
K2
K3
VT100
RS232
+15V
-15V
-5V
+28V
+28V CCV
CCV GND
AN GND
DIG GND
GND
A2
A3
AUTOMATED THREAD INSPECTION CONTROLLER
+28V
+15V
-15V
AN. GND
DIG. GND
CALIBRATION DATA (6)
OPERATION DATA (6)
THRESHOLD DATA (6)
RESET
OPTO SWITCH
CURRENT MONITOR
GND
OPTO IN
OPTO OUT
OPTO GND
MOTOR ENA
MOTOR EN GND
MOTION COMPLETE
A4
MOTOR CONTROLLER
CURRENT MONITOR RETURN
CURRENT MONITOR SIGNAL
MOTOR ENABLE
MOTOR ENABLE GND
+28V CCV
CCV RETURN
J8(19)/J2(20)
J8(18)/J2(22)
J8(17)/J2(23)
PINS 1 → 15
AND 20,21,22,24,25
GND
-VOUT
+VOUT
(+IN) +28V
(-IN) AV GND
P1
J1
P2
J2
P3
J3
P4
J4
P8
J8
J10
J11
ITM12
THREAD INSPECTION STATION
D
13160
1/6/1987
REFERENCE ONLY

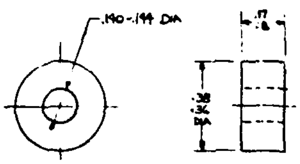
1. BREAK ALL SHARP CORNERS .005-.015 RAD OR CHAM.







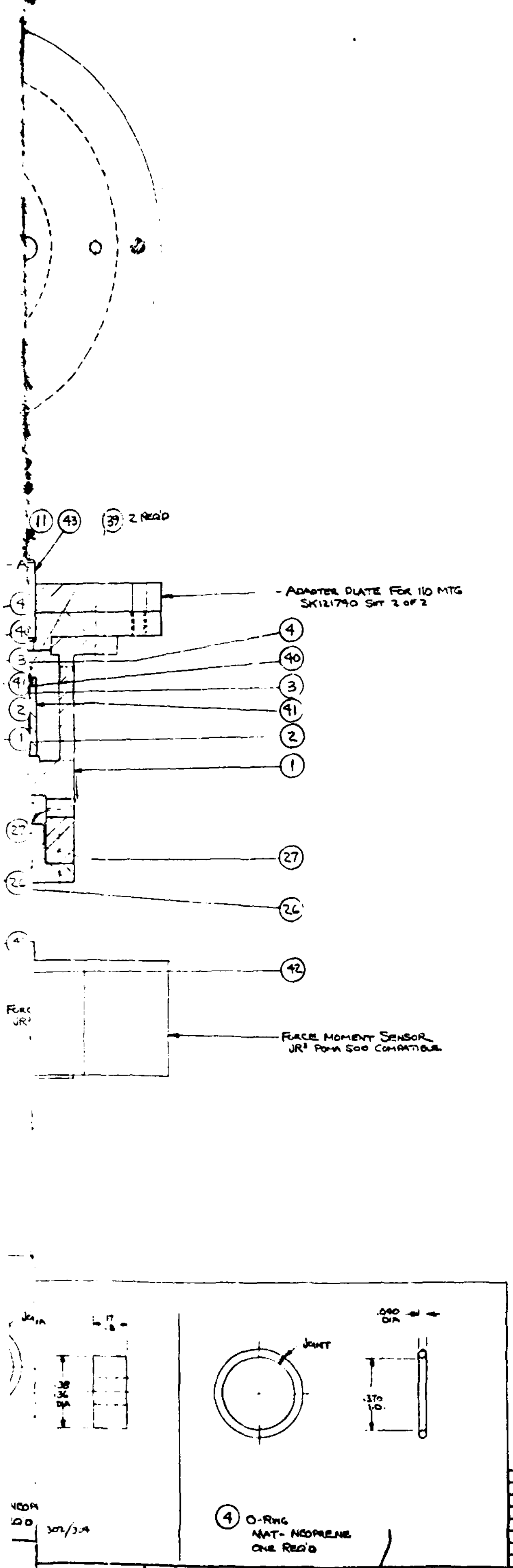
38 PILOT PLUG
MAT- CRES 302/305
ONE REQ D



10 WASHER
MAT- CRES 302/304
4 REQ D

4 C

ZONE	LTR	DESCRIPTION	DATE	APPROVED
	A	ADDED SHEET 4 (D SIZE) WITH ITEMS 44 THRU 50	10/17/85	



ITEM	REQ'D	DESCRIPTION	MATERIAL
50		-SEE SHEET 4 (D SIZE)	
49			
48			
47		-	
46		-	
45		-	
44		- SEE SHEET 4 (D SIZE)	
43	1	DOWEL 6 MM (.2362) DIA × 7/8 LG	STEEL
42	1	DOWEL 3/16 DIA × 1/2 LG	STEEL
41	1	COVER, ENCODER	PURCH. PART OF ITEM 17
40	1	FELT SEAL	PURCH PART OF ITEM 17
39	2	#2-56 × 1" LG PAN HD SCR	
38	1	PILOT PLUG 1 3/8 O.D × 1" LG	CRES.
37	1	COVER .040 THICK × 1 1/2 × 6" LG	ALUM 6061-T6
36	1	BRACKET .050 THICK × 1 × 2	ALUM 6061-T6
35	10	#4-40 × 1/4 LG PAN HD SCR	MS 51957-13
34	1	COVER .040 THICK × 1 1/2 × 6" LG	ALUM 6061-T6
33	2	#2-56 × 1/4 LG SOC. HD SCR	MS 16995-2
32	1	BRACKET .050 THICK × 5/8" × 2"	ALUM 6061-T6
31	1	BRACKET .050 THICK × 2" × 2"	ALUM 6061-T6
30	2	CONNECTOR SREC50M49J WITH PINS	
29	2	#2-56 HEX NUT	
28	2	#2-56 × 3/16 LG PAN HD SCR	MS51957-2
27	1	DC TORQUE MOTOR # D-1938-A-2	PURCH
26	1 PAIR	MPB DUPLEX BRG # SB12MC	
25	1	SPINDLE 2 1/4 DIA × 2 1/2 LG	STEEL 4130
24	4	#4-40 × 3/8 LG 100° CSK HD SCREW	MS 21092-002
23	1	CLAMP RING 1 1/2 DIA × 3/8 THICK	ALUM 6061-T6
22	4	#2-56 × 5/16 LG 82° CSK HD SCREW	MS51959-8
21	4	#6-32 × 1/2 LG SOC HD SCR	MS 16995-18
20	1	BEARING PLATE 3 1/4 DIA × 1" THICK	ALUM 6061-T6
19	1	SPACER SLEEVE 3/4 DIA × 2" LG	STEEL 1020
18	1	NUT-SHAFT 1" DIA × 1" LG	STEEL 1020
17	1	ENCODER	PURCH - RENCO
16	3	# 2 FLAT WASHER	
15	3	#2-56 × 3/16 LG SOC. HD. SCR (CUT OFF 1/4 LONG SCR)	MS16995-4
14			
13	1	SHIELD	
12	1	RESTRAINT .050 THICK × 3/4 × 2"	ALUM 6061-T6
11	1	SLIP RING CAPSULE ASSY DRWG # 192901C	PURCH
10	4	SPACER WASHER 3/8 DIA × 1/4 LG	CRES 302/304
9	12	#6-32 × 1 1/2 DIA LG HELICAL INSERT - SELF LOCK	
8	1	TOP PLATE 1/2 THICK × 5 1/4 DIA	ALUM 6061-T6
7	8	#6 FLAT WASHER	CRES
6	8	#6-32 × 5/8 LG SOCK. HD SCR.	MS16995-19
5	2	#60 UNM (.0236 DIA) × 1/8 LG BINDING HD SCR	MS21271A2G-60UM
4	1	O-RING .364 I.D. × .070 PARKER # 2-012	NEOPRENE
3	1	EXTENSION - SPINDLE 5/8 DIA × 2" LG	ALUM 6061-T6
2	1	BALL BEARING MPB SB12MC	
1	1	HOUSING 4 1/4 DIA × 2 3/4 LG	ALUM 6061-T6

PARTS LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE
FRACTIONS ± DECIMALS .XX ± .XXX ± ANGLES ±
MATERIAL
FINISH
DO NOT SCALE DRAWING

NEXT ASSY | USED ON
APPLICATION

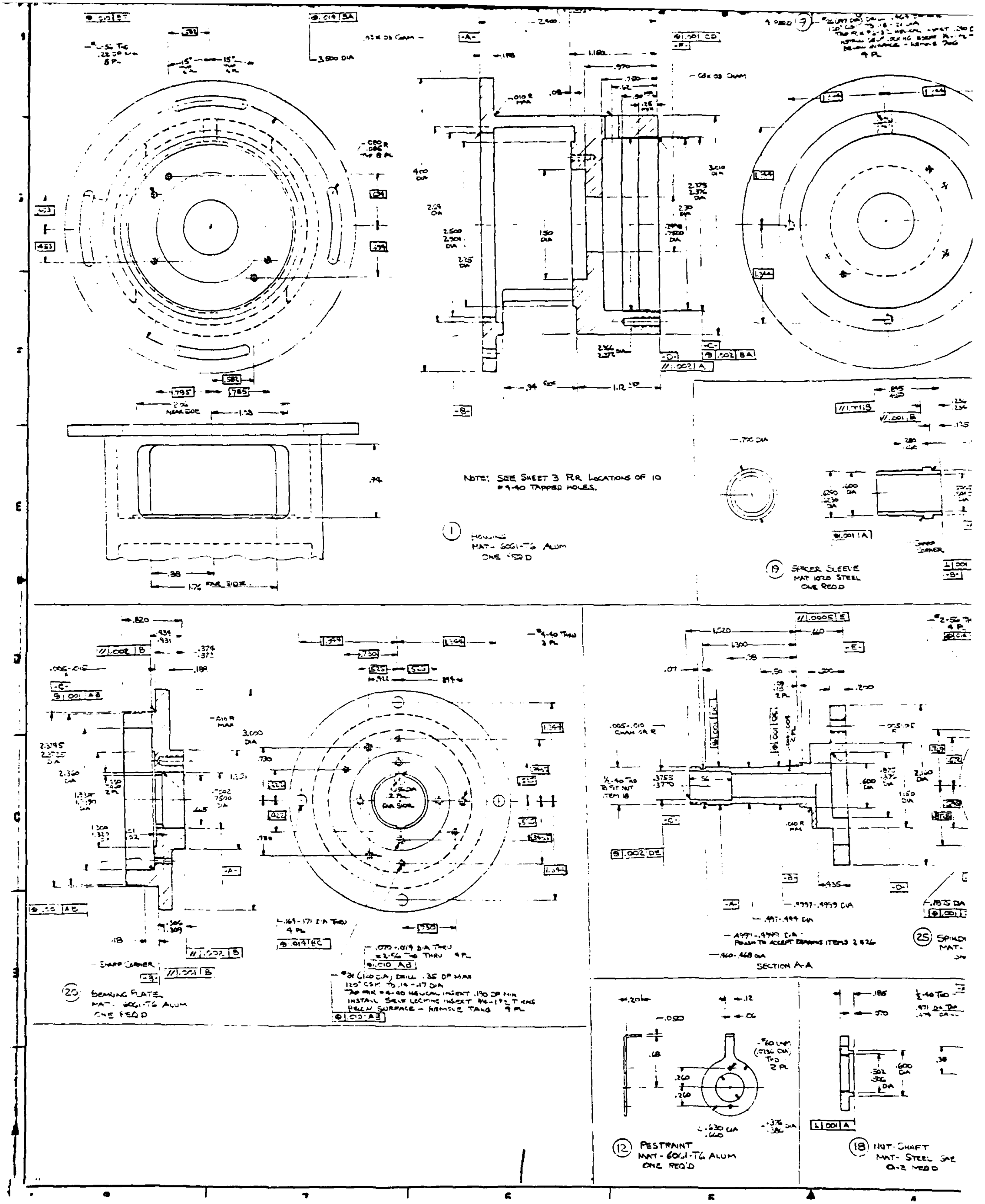
CONTRACT NO. W.A 460102

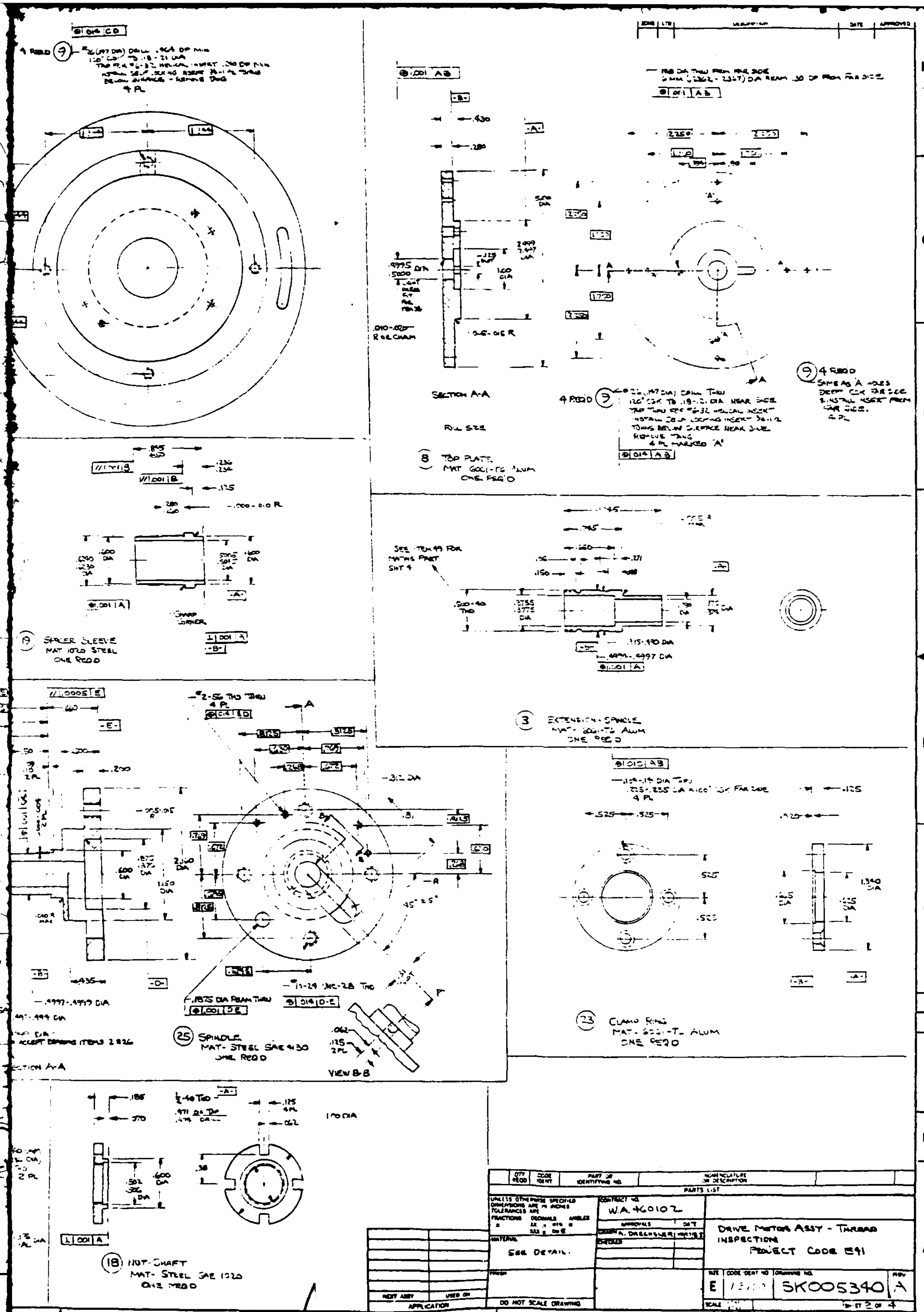
APPROVALS		DATE
DRAWN	A. DRECHSLER	10/1/85
CHECKED		

DRIVE MOTOR ASSY - THREAD INSPECTION ITM PROJECT 12 PROJECT CODE E41

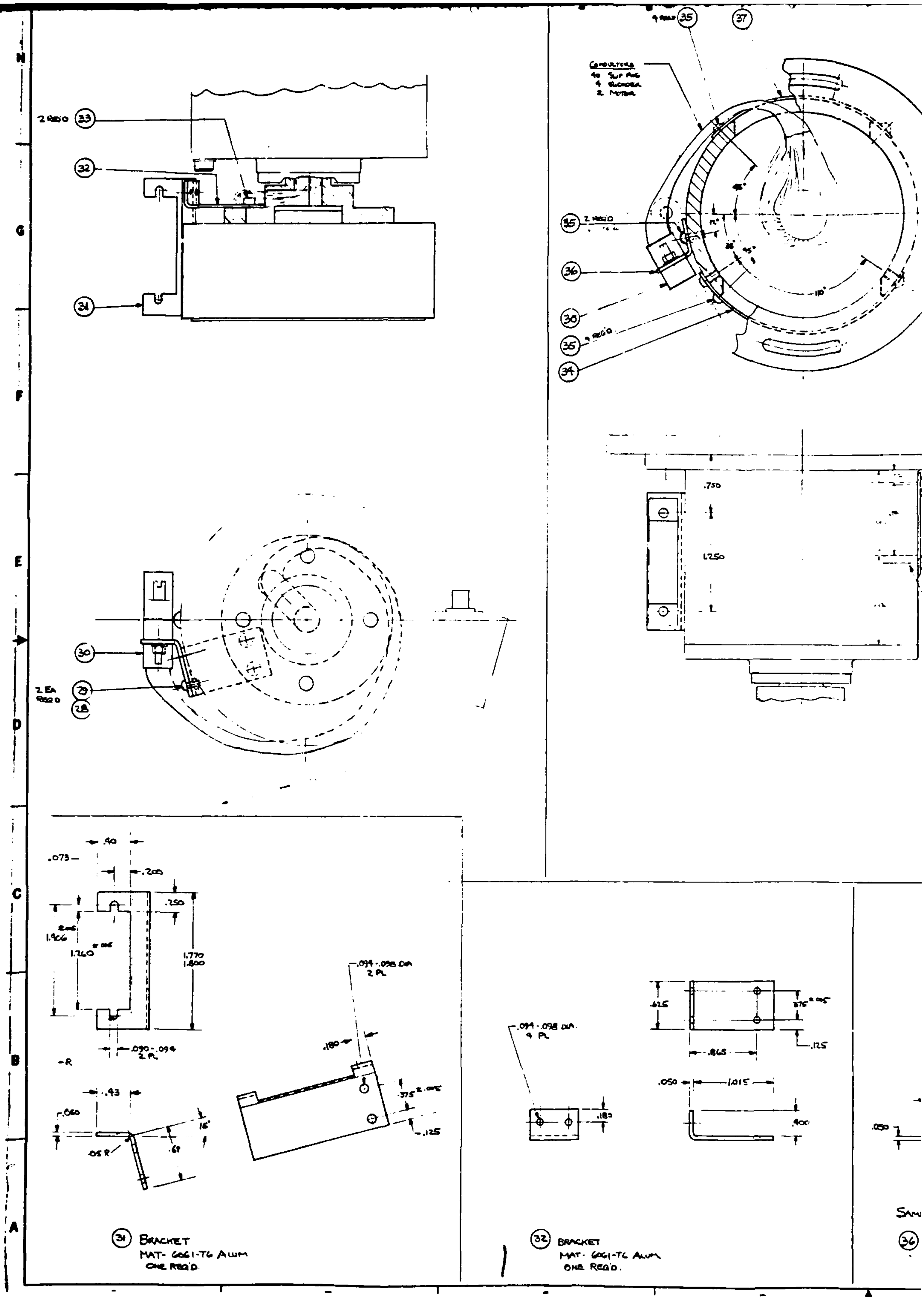
SIZE	CODE IDENT NO.	DRAWING NO.	REV
E	13160	SK005340	A

SCALE | SHEET 1 OF 4

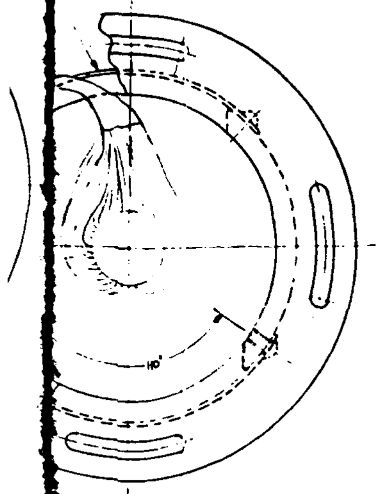

NOTE: SEE SHEET 3 FOR LOCATIONS OF 10 #4-40 TAPPED HOLES.
1 HOUSING MAT- 6061-T6 ALUM ONE REQ'D
19 SPACER SLEEVE MAT 1020 STEEL ONE REQ'D
20 BEARING PLATE MAT- 6061-T6 ALUM ONE REQ'D
SECTION A-A
12 RESTRAINT MAT- 6061-T6 ALUM ONE REQ'D
18 NUT-SHAFT

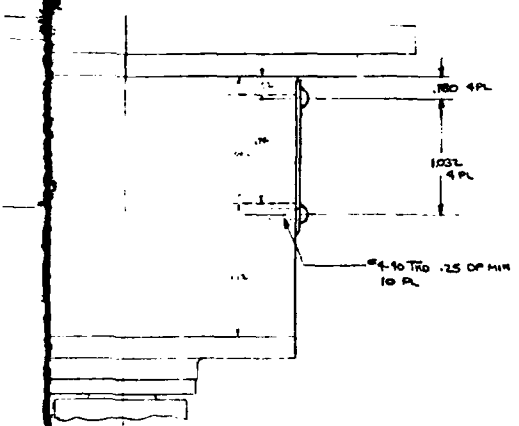


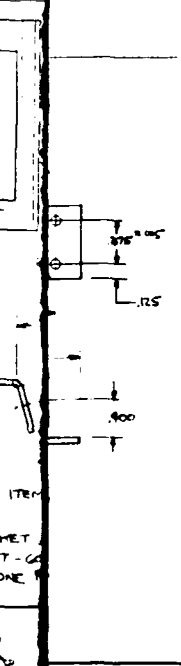
SECTION A-A
FULL SIZE
8 TOP PLATE
MAT 6061-T6 ALUM
ONE REQ'D
19 SPACER SLEEVE
MAT 1020 STEEL
ONE REQ'D
3 EXTENSION - SPINDLE
MAT 6061-T6 ALUM
ONE REQ'D
25 SPINDLE
MAT - STEEL SAE 4130
ONE REQ'D
VIEW B-B
23 CLAMP RING
MAT - 6061-T6 ALUM
ONE REQ'D
18 NUT - SHAFT
MAT - STEEL SAE 1020
ONE REQ'D
PARTS LIST
W.A. 460102
A. DREHSLER
SEE DETAIL
DRIVE MOTOR ASSY - THREAD INSPECTION
PROJECT CODE 1541
SK005340
A
DO NOT SCALE DRAWING
APPLICATION

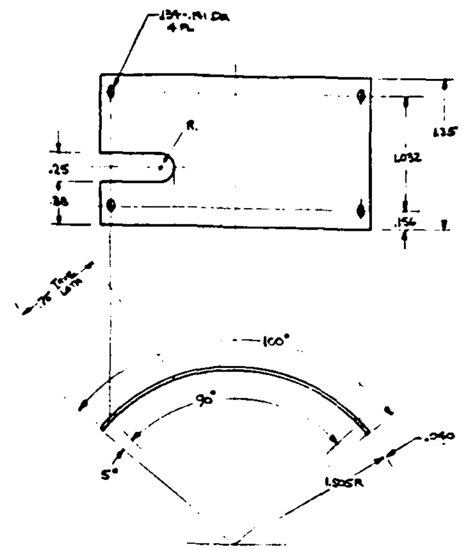


H
G
F
E
D
C
B
A
2 REQ'D 33
32
31
4 REQ'D 35
37
CONDUCTORS
40 SLIP RING
4 ENCODER
2 MOTOR
35 2 REQ'D
36
30
35 4 REQ'D
34
110°
.750
1.250
30
2 EA REQ'D 29
28
.40
.073
.200
.250
1.906
1.760
1.770
1.800
.094-.098 DIA
2 PL
.090-.094
2 PL
.43
.060
.05 R
.69
16°
.180
.375 ±.005
.125
31 BRACKET
MAT- 6061-T6 ALUM
ONE REQ'D
.094-.098 DIA.
4 PL
.185
.625
.375 ±.005
.125
.865
.050
1.015
.400
32 BRACKET
MAT- 6061-T6 ALUM
ONE REQ'D
.050
36

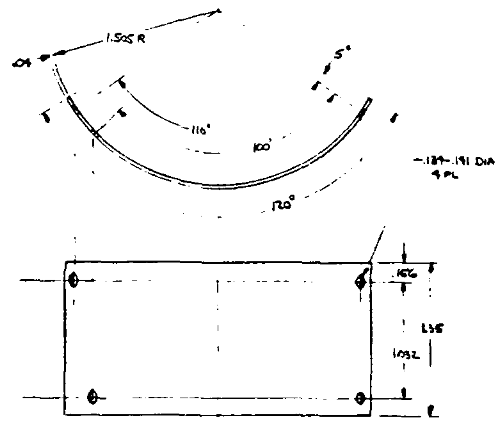




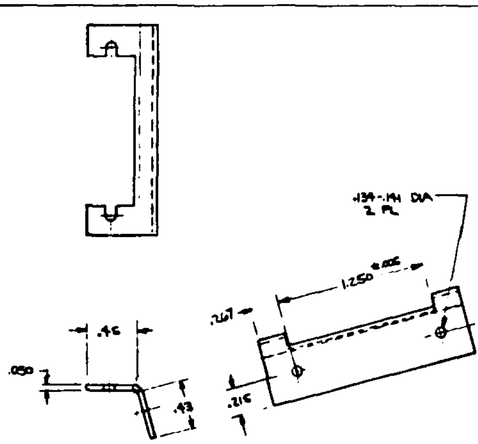




(37) COVER
MAT - 6061-T6 ALUM
ONE REQ'D



(34) COVER
MAT - 6061-T6 ALUM
ONE REQ'D



SAME AS ITEM 31 EXCEPT AS SHOWN

(36) BRACKET
MAT - 6061-T6 ALUM
ONE REQ'D

NOTE: TOLERANCES ON SHEET METAL PARTS UNLESS OTHERWISE SPECIFIED
.XX ±.015
.XXX ±.010

QTY REQD	CODE IDENT	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION
PARTS LIST			

CONTRACT NO. W.A. 460102

MATERIAL: SEE L/M

DRIVE MOTOR ASSY - THREAD INSPECTION

PROJECT CODE E41

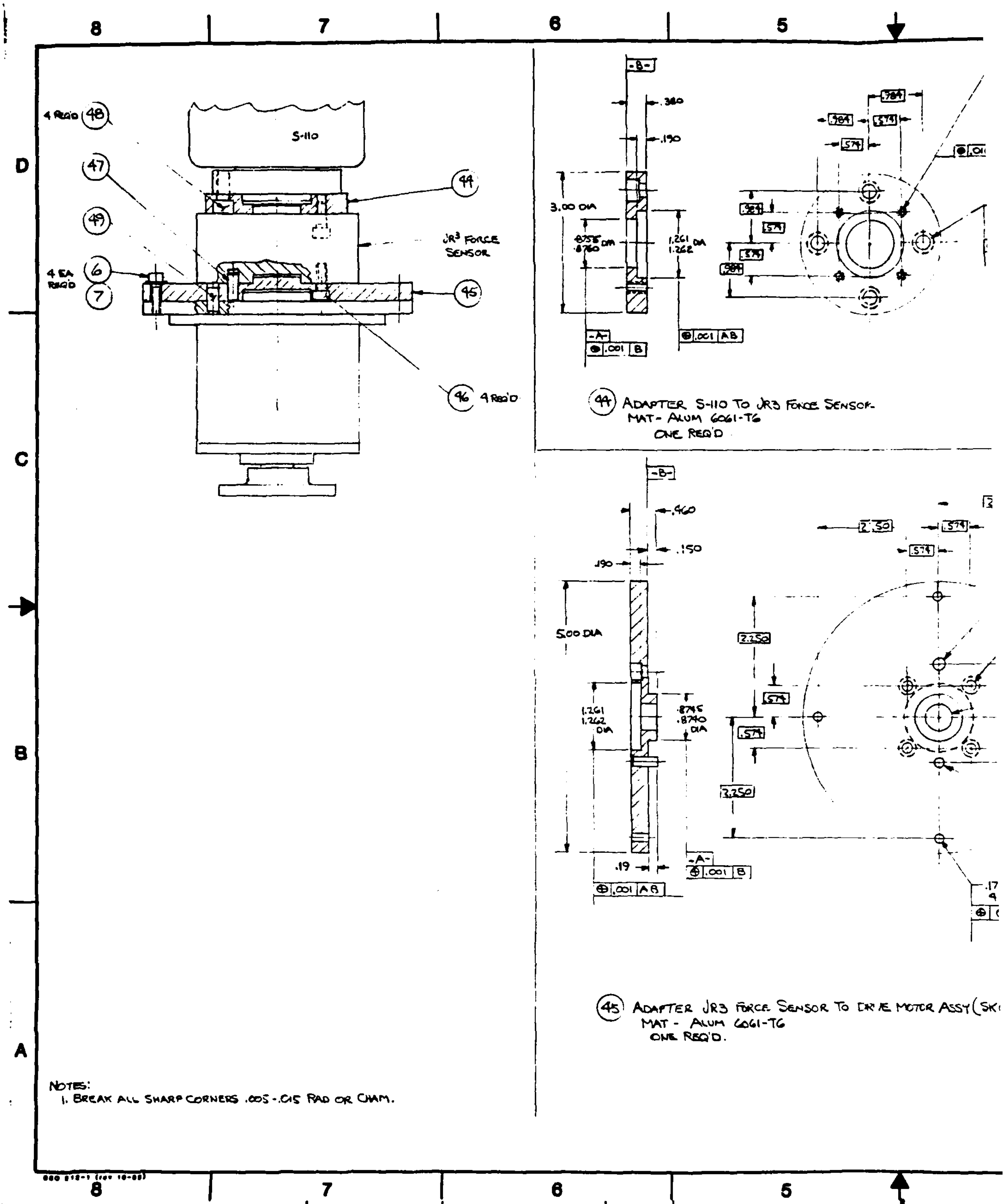
SIZE E | DWG NO. SK005390 | REV A

SCALE 2X SIZE | SHEET 3 OF 4

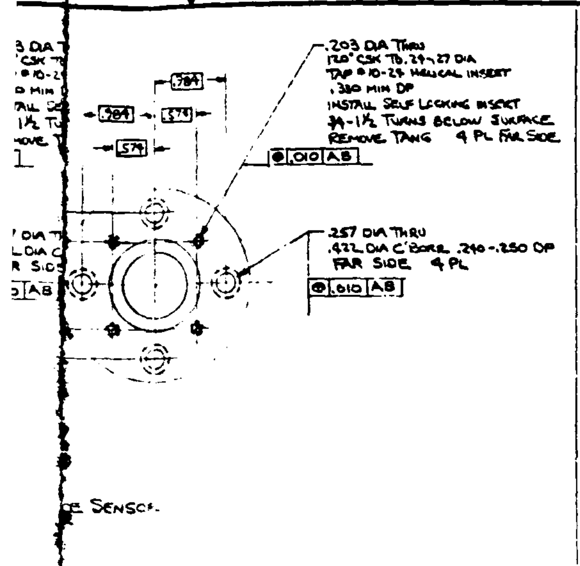
NEXT ASSY | USED ON
APPLICATION

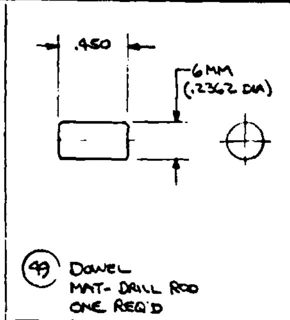
DO NOT SCALE DRAWING

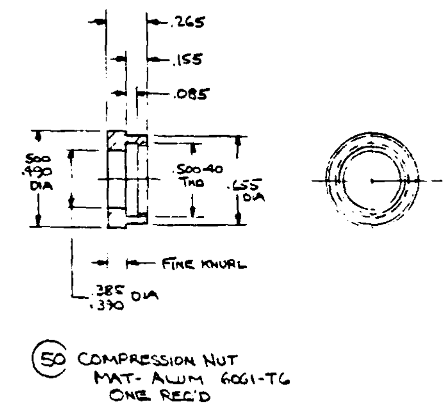
2

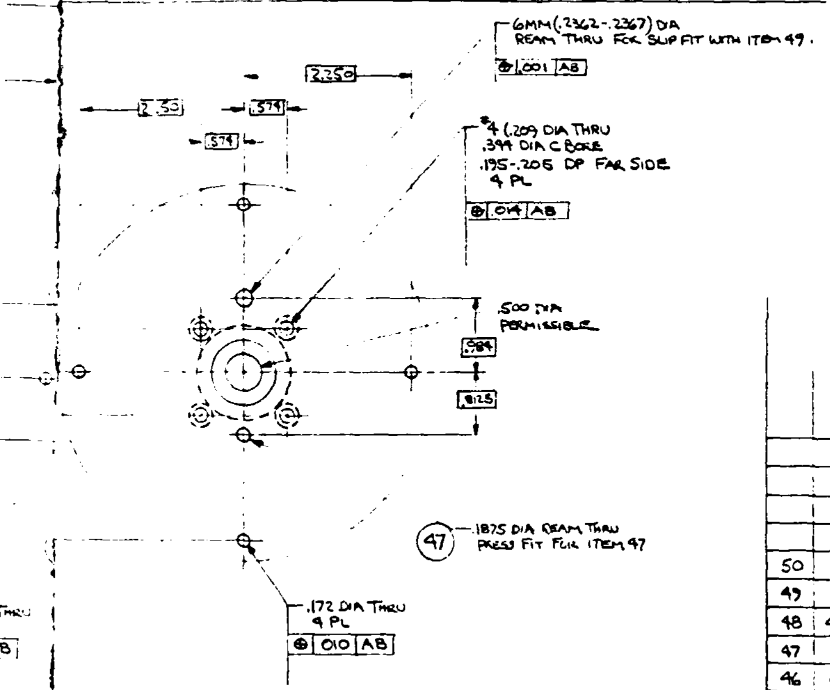


8
7
6
5
D
C
B
A
4 REQ'D 48
47
49
4 EA REQ'D 6
7
S-110
44
JR³ FORCE SENSOR
45
46 4 REQ'D
-B-
.380
.190
3.00 DIA
.8755 DIA
.8760
1.261 DIA
1.262
.984
.574
-A-
.001 B
.001 A B
44 ADAPTER S-110 TO JR3 FORCE SENSOR
MAT - ALUM 6061-T6
ONE REQ'D
.460
.150
.190
5.00 DIA
2.50
2.250
1.261
1.262
DIA
.8745
.8740
DIA
.19
45 ADAPTER JR3 FORCE SENSOR TO DRIVE MOTOR ASSY (SK
MAT - ALUM 6061-T6
ONE REQ'D.
NOTES:
1. BREAK ALL SHARP CORNERS .005-.015 RAD OR CHAM.









SOR TO DRIVE MOTOR ASSY (SK005340)

ITEM	REQD	DESCRIPTION		MATERIAL
50	1	COMPRESSION NUT	½ DIA X 1" LG	ALUM 6061-T6
49	1	DOWEL 6MM (.2362 DIA) X .450 LG		DRILL ROD
48	4	SOC HD SCR M6 X 1 X 14 MM LG		
47	1	DOWEL	3/16 DIA X ½ LG	STOCK
46	4	SOC HD SCR	#10-24 X ½ LG	
45	1	ADAPTER	½ THICK X 5¼ DIA	ALUM 6061-T6
44	1	ADAPTER	3¼ DIA X ½ THICK	ALUM 6061-T6

THE PART NUMBER IS THE DRAWING NUMBER AND THE DASH NUMBER THAT APPLIES

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES ON: 2 PLACE DECIMALS ±.010; 3 PLACE DECIMALS ±.005; ANGLES ±

MATERIAL

INTERPRET DRAWING PER DOD STD-100

CONTR NO.
DFTA A. DRECHSLER 12/17/85
CHKR
ENGR
APVD / APVD
APVD / APVD
DSGN ACTIVITY APVD
DO NOT SCALE DWG — REF E-41

Delco Systems Operations
GENERAL MOTORS CORPORATION — GOLETA, CALIFORNIA

TITLE: DRIVE MOTOR ASSEMBLY. ADAPTERS TO PUT FORCE SENSOR (JR³) ON TOP.

SIZE D | FSCM NO. 13160 | DWG NO. SK005340 | REV A
SCALE | SHEET 4 OF 4

REVISIONS
ZONE	REV	DESCRIPTION	AUTH.	DATE	APPROVED

REV —

DWG NO. SK100474

REVISIONS				
REV	DESCRIPTION	AUTH	DATE	APPROVED

REVISION	—	—	—																								
SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27

THE PART NUMBER IS THE DRAWING NUMBER AND THE DASH NUMBER THAT APPLIES

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES

TOLERANCES ON

2 PLACE DECIMALS	3 PLACE DECIMALS	ANGLES
± —	± —	± —

MATERIAL —

INTERPRET DRAWING PER DOD-STD-100

CONTR. NO.

DFT S. Allen 87-4-29

CHKR

ENGR [illegible] 87-4-29

APVD | APVD

APVD | APVD

DSGN ACTIVITY APVD

DO NOT SCALE DWG

REF E41

Delco Systems Operations

GENERAL MOTORS CORPORATION GOLETA, CALIFORNIA

TITLE EOAT ASSY

SIZE	FSCM NO.	DWG NO.	REV
A	13160	SK100474	—

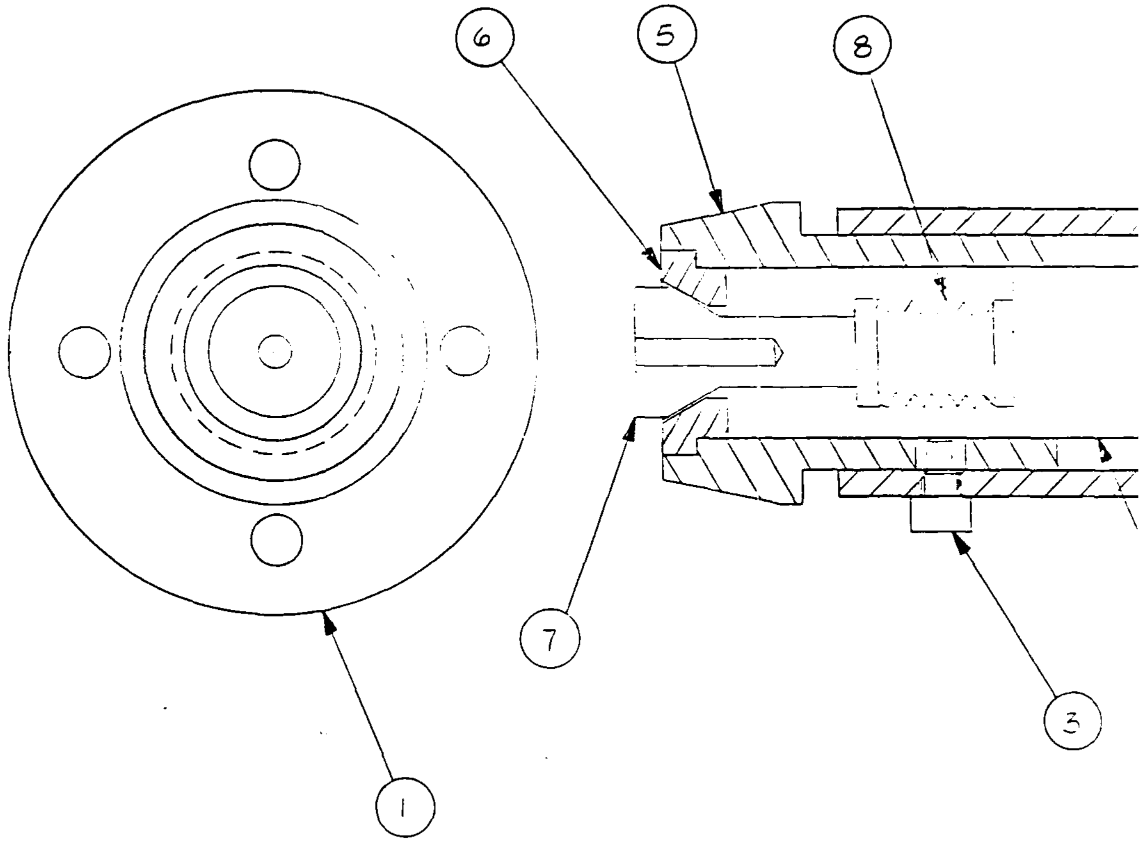
SCALE — SHEET 1 OF 3

Form 1127

4 3

D

C



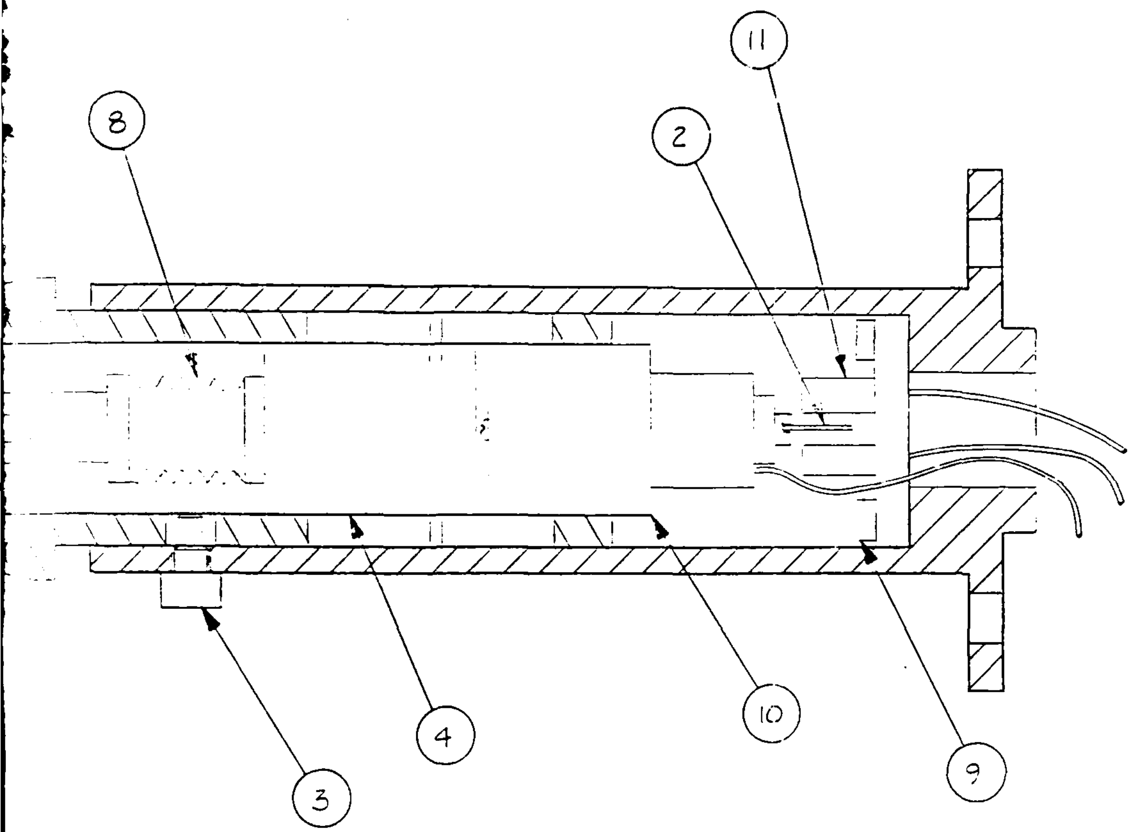
B

A

DSO 211-2 (rev 10-83)

4 3

REVISIONS				
REV	DESCRIPTION	AUTH.	DATE	APPROVED



REFERENCE ONLY

SIZE	FSCM NO	DWG NO	REV
C	13160	SK100474	–
SCALE 2/1		SHEET 2	

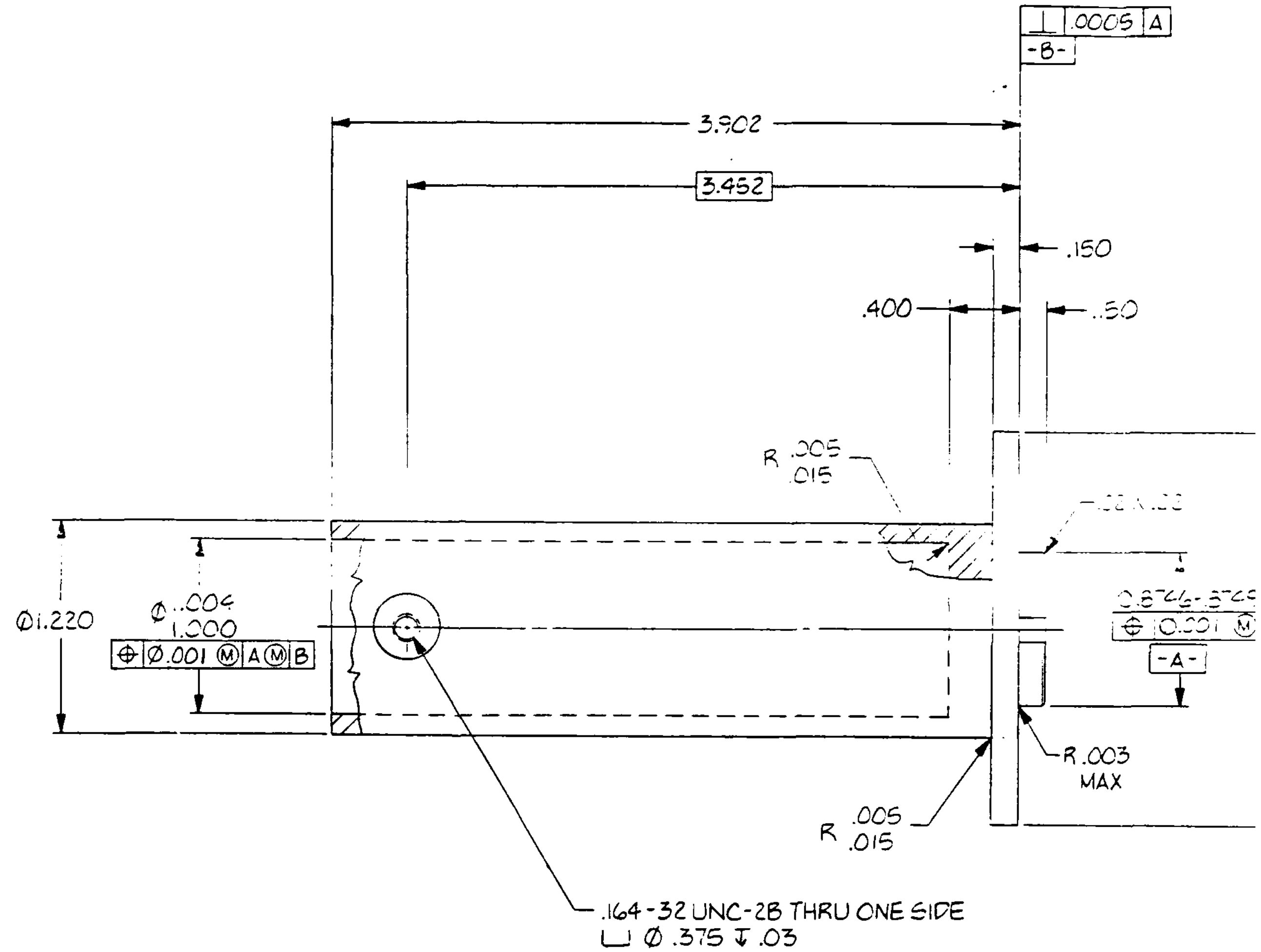
PARTS LIST		CONTRACT NO.	FSCM 13160	SK100474	REV LTR –
LIST TITLE EOAT ASSY	AUTHENTICATION	REVISION AUTH NO.		REV DATE	SH 3

FIND NO.	QTY REQD	QTY REQD	QTY REQD	QTY REQD -011	UNIT OF MEAS	FSCM	PART OR IDENTIFYING NUMBER	DRAWING OR DOCUMENT NUMBER	NOMENCLATURE OR DESCRIPTION	PL NOTES
1				1			SK100473-001		SHELL	
2				1			SK100472-001		FLAG, INTERRUPT	
3				1			SK100471-001		SCREW, LOCKING	
4				1			SK100470-001		PISTON	
5				1			SK100468-001		SLIDER	
6				1			SK100467-001		MOUNT GAGE	
7				1			SK100466-001		NUT, END	
8				1			FC-9		BELLOWS (SERVOMETER)	
9				2					SCREW 4-40 X .25	
10				1			RIZX6		SOLENOID (REGDON)	
11				1			TIL143		SENSOR (TI)	

Form 1151A

NOTES:

1. REMOVE BURRS AND BREAK SHARP EDGES.

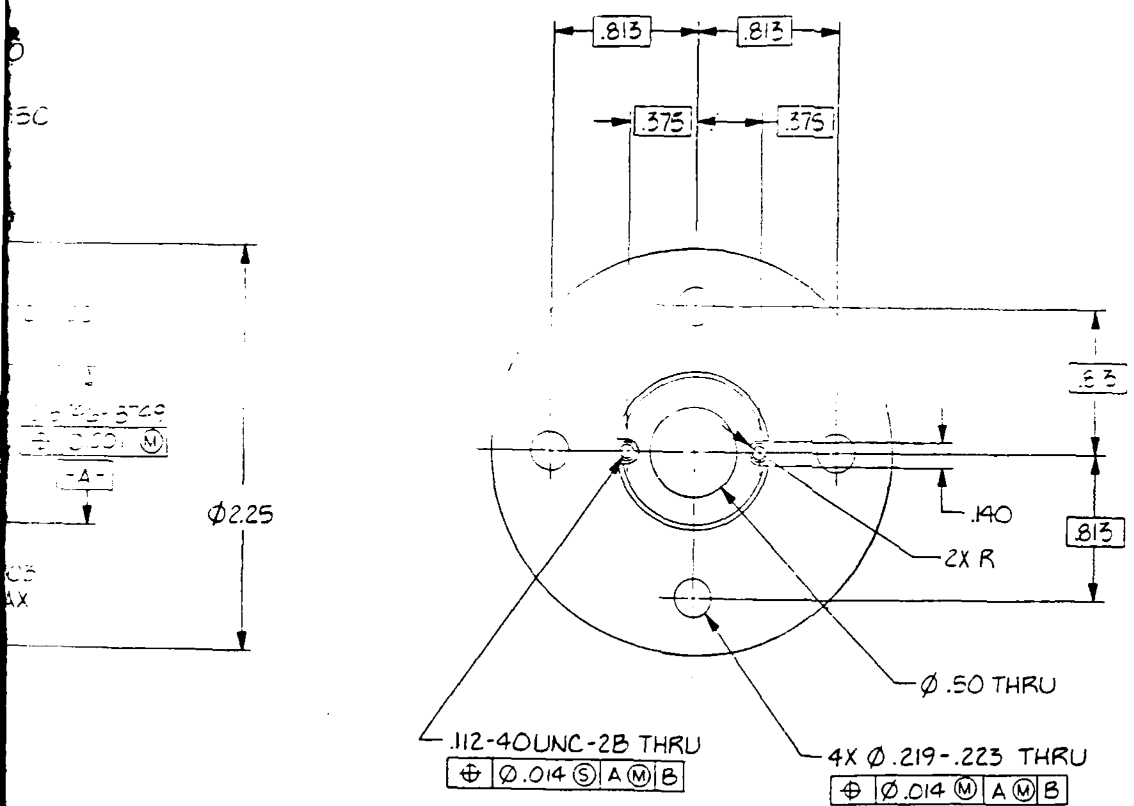


DSO 212-1 (rev 10-83)

8 7 6 5

ZONE	REV	DESCRIPTION	AUTH.	DATE	APPROVED

REVISIONS



REFERENCE ONLY

THE PART NUMBER IS THE DRAWING NUMBER AND THE DASH NUMBER THAT APPLIES

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES

TOLERANCES ON

2 PLACE DECIMALS	3 PLACE DECIMALS	ANGLES
±.01	±.005	± –

MATERIAL
AL ALLOY
6061-TEMPER T6

INTERPRET DRAWING PER DOD-STD-100

CONTR. NO. —
DFT S. Allen 87-4-28
CHKR
ENGR 87-4-29
APVD APVD
APVD APVD
DSGN ACTIVITY APVD
DO NOT SCALE DWG REF E41

Delco Systems Operations
GENERAL MOTORS CORPORATION GOLETA, CALIFORNIA

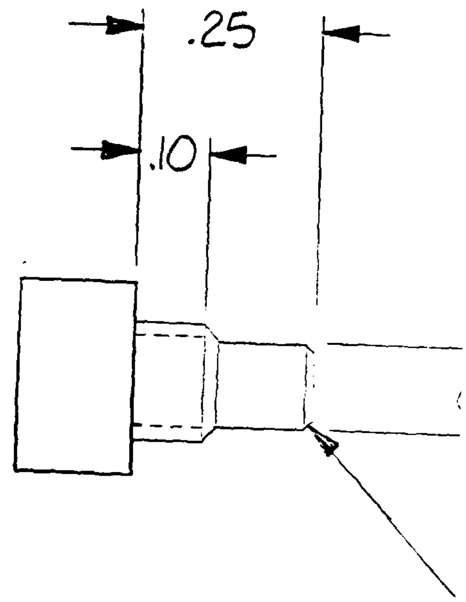
TITLE
SHELL

SIZE	FSCM NO.	DWG NO.	REV
D	13160	SK100473	–

SCALE 2/1 SHEET OF

NOTES:

1. MAKE FROM MS16995-25.



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2 PLAC
DECIMA
± .0

MATE
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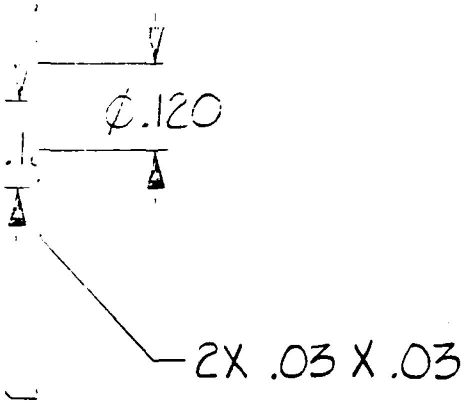
100410

DSO 210-1 (REV 6-84)

REVISIONS

REV	DESCRIPTION	AUTH.	DATE	APPROVED



REFERENCE ONLY

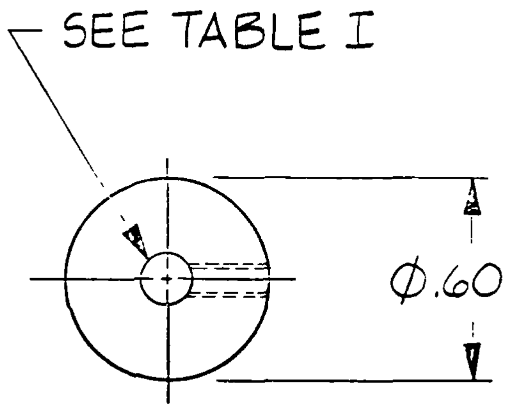
THE PART NUMBER IS THE DRAWING NUMBER AND THE DASH NUMBER THAT APPLIES

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON 2 PLACE DECIMALS ± .02 · 3 PLACE DECIMALS ± .005 · ANGLES ± —	CONTR. NO —	**Delco Systems Operations** GENERAL MOTORS CORPORATION · GOLETA, CALIFORNIA	
	DFT S. Allen · 87-4-27		
	CHKR		
MATERIAL SEE NOTE 1	ENGR [signature] · 87-4-29	TITLE SCREW, LOCKING	
	APVD · APVD		
	DSGN ACTIVITY APVD	SIZE B · FSCM NO. 13160 · DWG NO. SK100471	REV —
INTERPRET DRAWING PER DOD-STD-100	DO NOT SCALE DWG · REF E41	SCALE 4/1	SHEET 1 OF 1

NOTES:

1. MATL: STEEL CRES
TYPE 303 SE OR 303 SU
COND A.

2. REMOVE BURRS AND
BREAK SHARP EDGES.



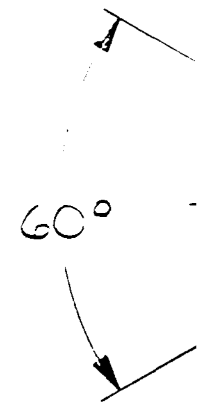


TABLE I

PN	HOLE DIA
-001	Ø .1505/.1500 ↧ .60
-002	Ø .1005/.1000 ↧ .60

TI

UNLESS OTHE
DIMENSIONS

TOLER

2 PLACE DECIMALS ± —

3 DE ±

MATERIAL

SEE N

INTERPRET
DOD-

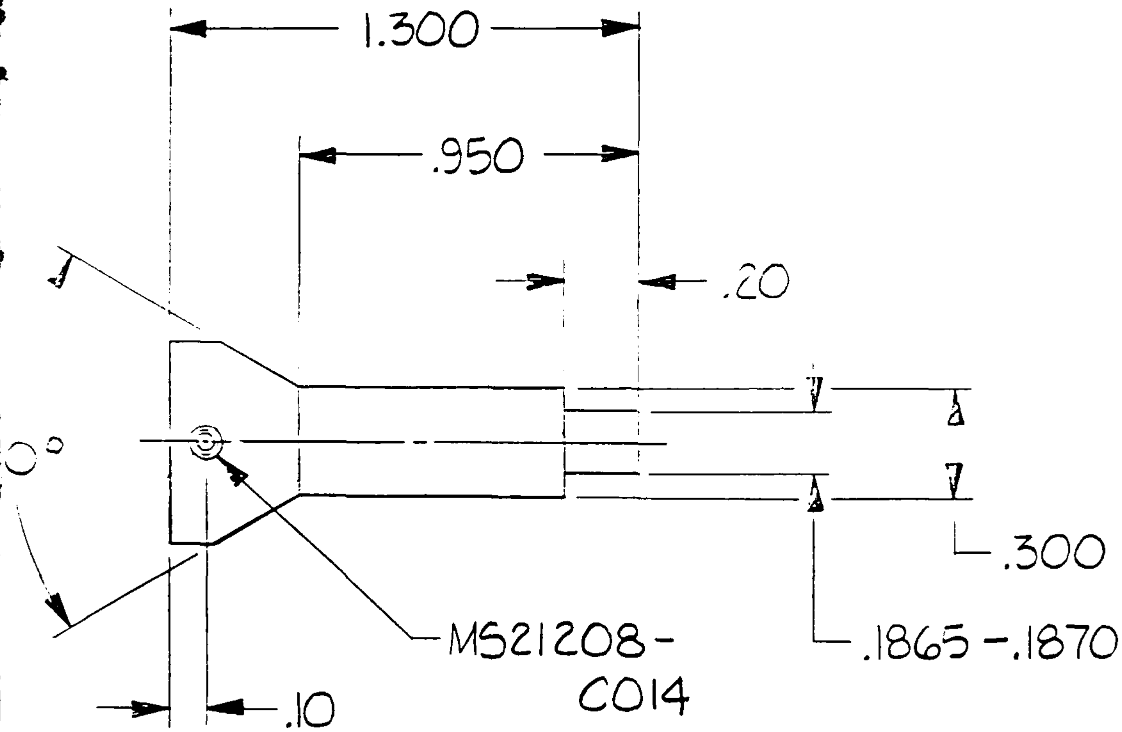
100410

DSO 210-1 (REV 6-84)

DWG 5K100467 | HS

REVISIONS

REV	DESCRIPTION	AUTH.	DATE	APPROVED



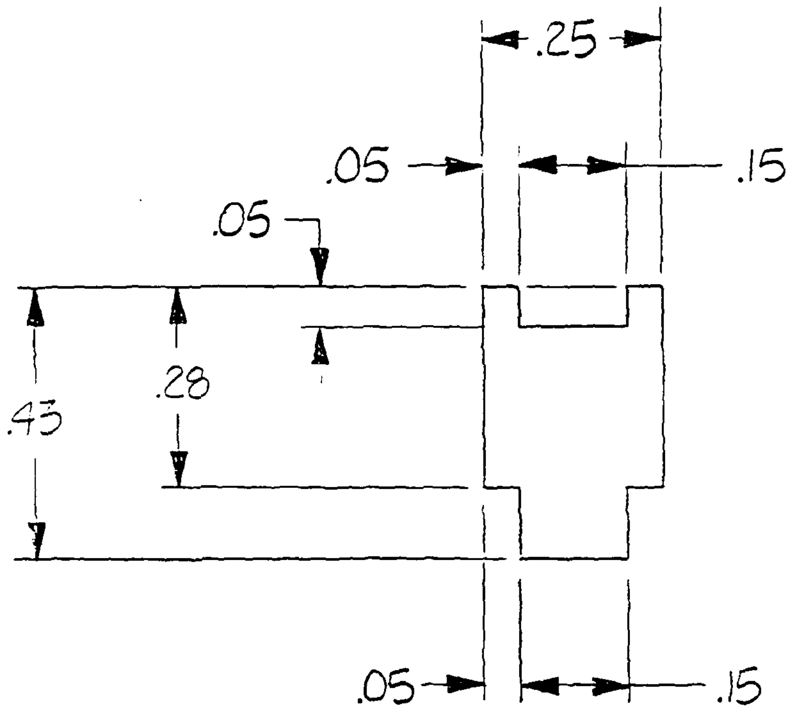
REFERENCE ONLY

THE PART NUMBER IS THE DRAWING NUMBER AND THE DASH NUMBER THAT APPLIES

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON 2 PLACE DECIMALS ± — 3 PLACE DECIMALS ± .005 ANGLES ± 1°	CONTR. NO — DFT S. Allen 87-4.24 CHKR ENGR [signature] 87-4-29 APVD / APVD	Delco Systems Operations GENERAL MOTORS CORPORATION GOLETA, CALIFORNIA	
MATERIAL SEE NOTE 1	DSGN ACTIVITY APVD	TITLE MOUNT, GAGE	
INTERPRET DRAWING PER DOD-STD-100	DO NOT SCALE DWG / REF E41	SIZE B / FSCM NO. 13160 / DWG NO. 5K100467 / REV —	SCALE 2/1 / SHEET 1 OF 1

NOTES:

1. MATL: AL ALLOY 6061-TEMPER T6, .040 THK
2. REMOVE BURRS AND BREAK SHARP EDGES.



UNLESS OT
DIMENSION
TOLE
2 PLACE DECIMALS
± .02

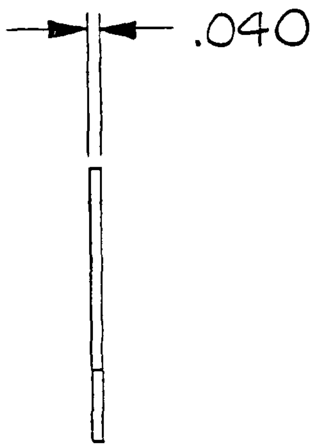
MATERIAL
AL AL

INTERPRE
DOD

100410

DSO 210-1 (REV 6-84)

REVISIONS				
REV	DESCRIPTION	AUTH.	DATE	APPROVED



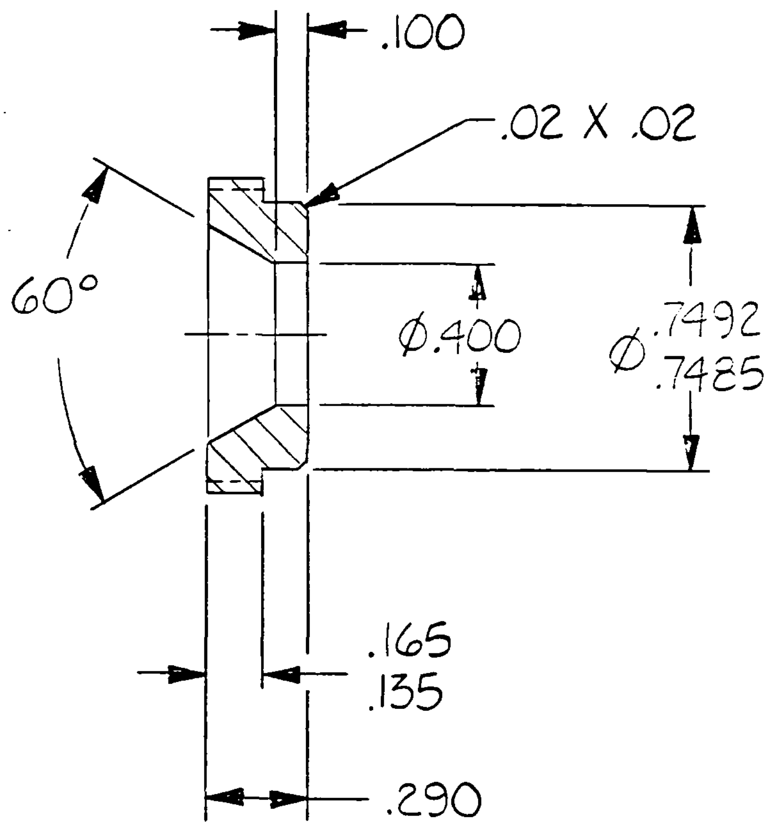
REFERENCE ONLY

THE PART NUMBER IS THE DRAWING NUMBER AND THE DASH NUMBER THAT APPLIES

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON 2 PLACE DECIMALS ± .02 · 3 PLACE DECIMALS ± · ANGLES ± —	CONTR. NO		Delco Systems Operations GENERAL MOTORS CORPORATION · GOLETA, CALIFORNIA
	DFT S. Allen		
	CHKR		TITLE FLAG INTERRUPT
	ENGR [signature]	87-4-27	
MATERIAL AL ALLOY 6061	APVD	APVD	
	DSGN ACTIVITY APVD		SIZE B · FSCM NO. 13160 · DWG NO. SK100466 · REV —
INTERPRET DRAWING PER DOD-STD-100	DO NOT SCALE DWG	REF E41	SCALE 4/1 · SHEET 1 OF 1

NOTES:

1. MATL: STEEL CRES
   TYPE 303 SE OR 303 SU
   COND A
2. REMOVE BURRS AND
   BREAK SHARP EDGES.



TH

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2 PLACE DECIMALS ± .01

3 DE ±

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100410

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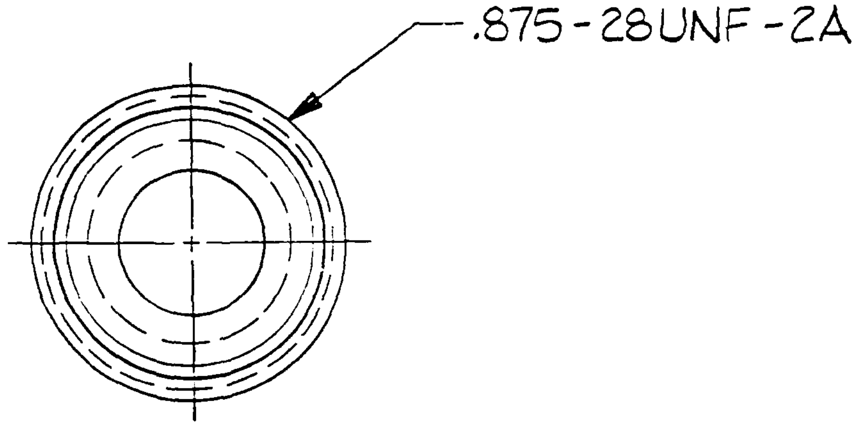
REVISIONS				
REV	DESCRIPTION	AUTH.	DATE	APPROVED



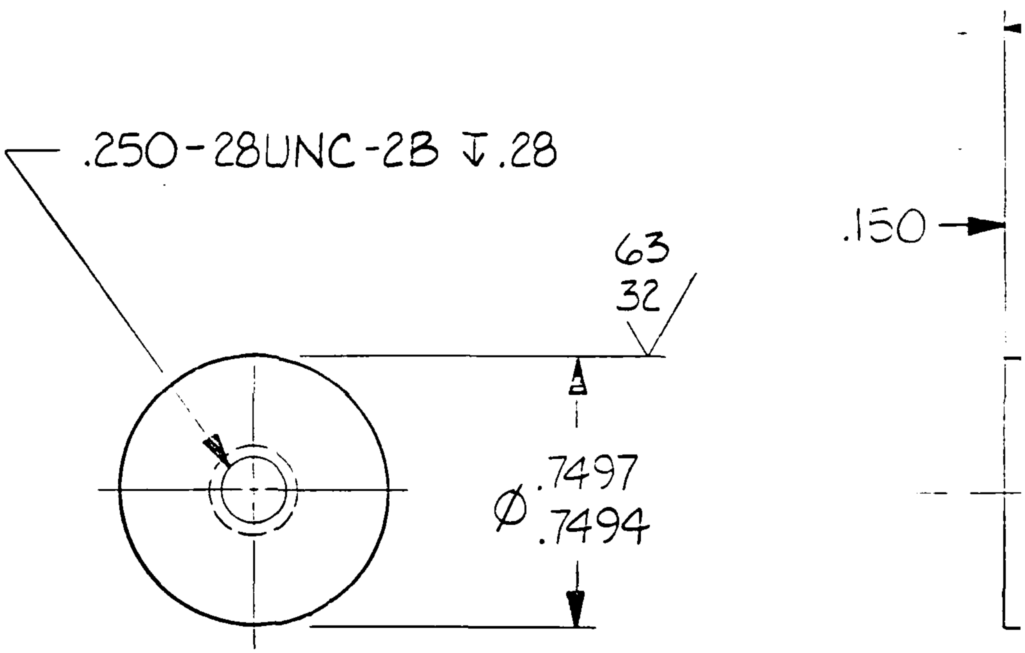
REFERENCE ONLY

THE PART NUMBER IS THE DRAWING NUMBER AND THE DASH NUMBER THAT APPLIES

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES	CONTR. NO		Delco Systems Operations GENERAL MOTORS CORPORATION GOLETA, CALIFORNIA	
TOLERANCES ON 2 PLACE DECIMALS ±.01 3 PLACE DECIMALS ±.005 ANGLES ±1°	DFT S. Allen	87-4-24	TITLE NUT, END	
	CHKR			
	ENGR [illegible]	87-4-29		
MATERIAL SEE NOTE 1	APVD	APVD	SIZE B / FSCM NO. 13160 / DWG NO. SK100466	REV –
	DSGN ACTIVITY APVD			
INTERPRET DRAWING PER DOD-STD-100	DO NOT SCALE DWG	REF E41	SCALE 2/1	SHEET 1 OF 1

NOTES:

1. MATERIAL: STEEL CRES TYPE 303 SE OR 303 SU CONDITION A.
2. REMOVE ALL BURRS AND BREAK SHARP EDGES.



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2 PLACE DECIMALS ± .02
MATERIAL
SEE
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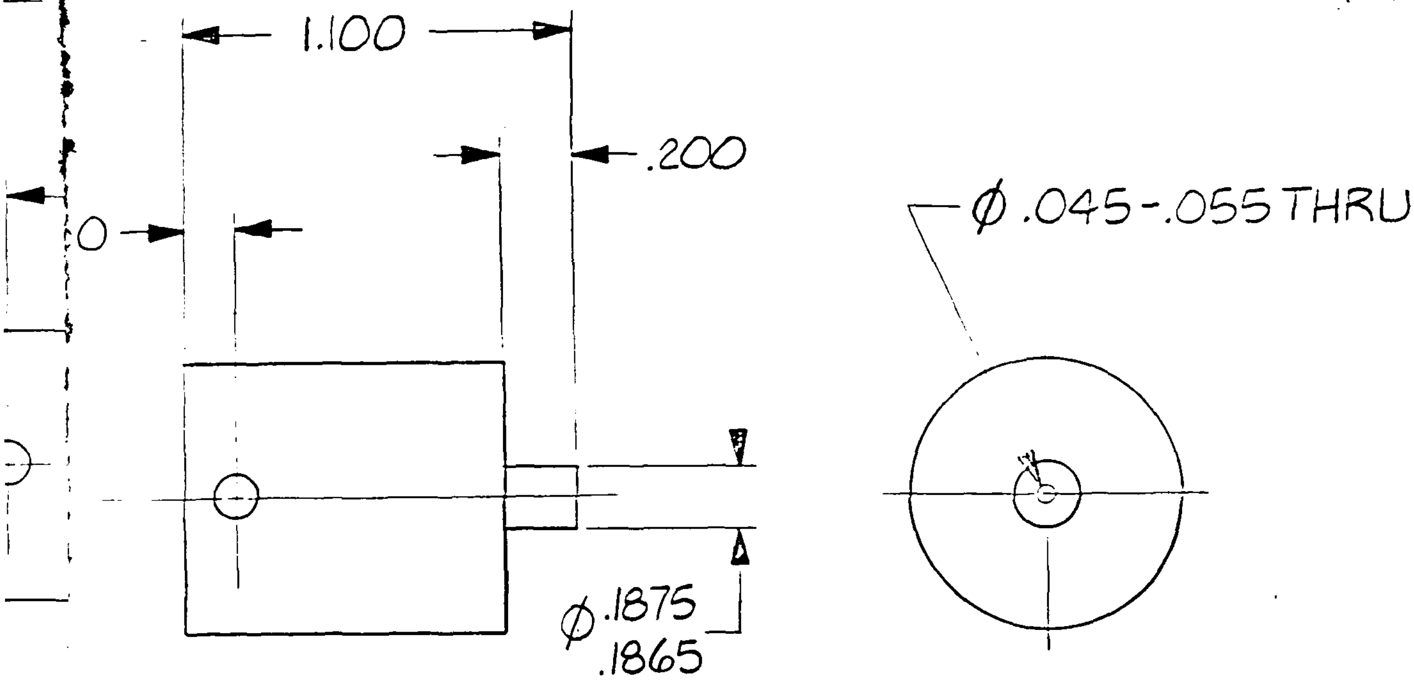
REVISIONS				
REV	DESCRIPTION	AUTH.	DATE	APPROVED



REFERENCE ONLY

THE PART NUMBER IS THE DRAWING NUMBER AND THE DASH NUMBER THAT APPLIES

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES

TOLERANCES ON

2 PLACE DECIMALS	3 PLACE DECIMALS	ANGLES
±.02	±.005	± —

MATERIAL: SEE NOTE 1

INTERPRET DRAWING PER DOD-STD-100

CONTR. NO	—	
DFT	S. Allen	87-4-27
CHKR		
ENGR	[signature]	87-4-29
APVD	APVD	
DSGN ACTIVITY APVD		
DO NOT SCALE DWG	REF E41	

Delco Systems Operations
GENERAL MOTORS CORPORATION — GOLETA, CALIFORNIA

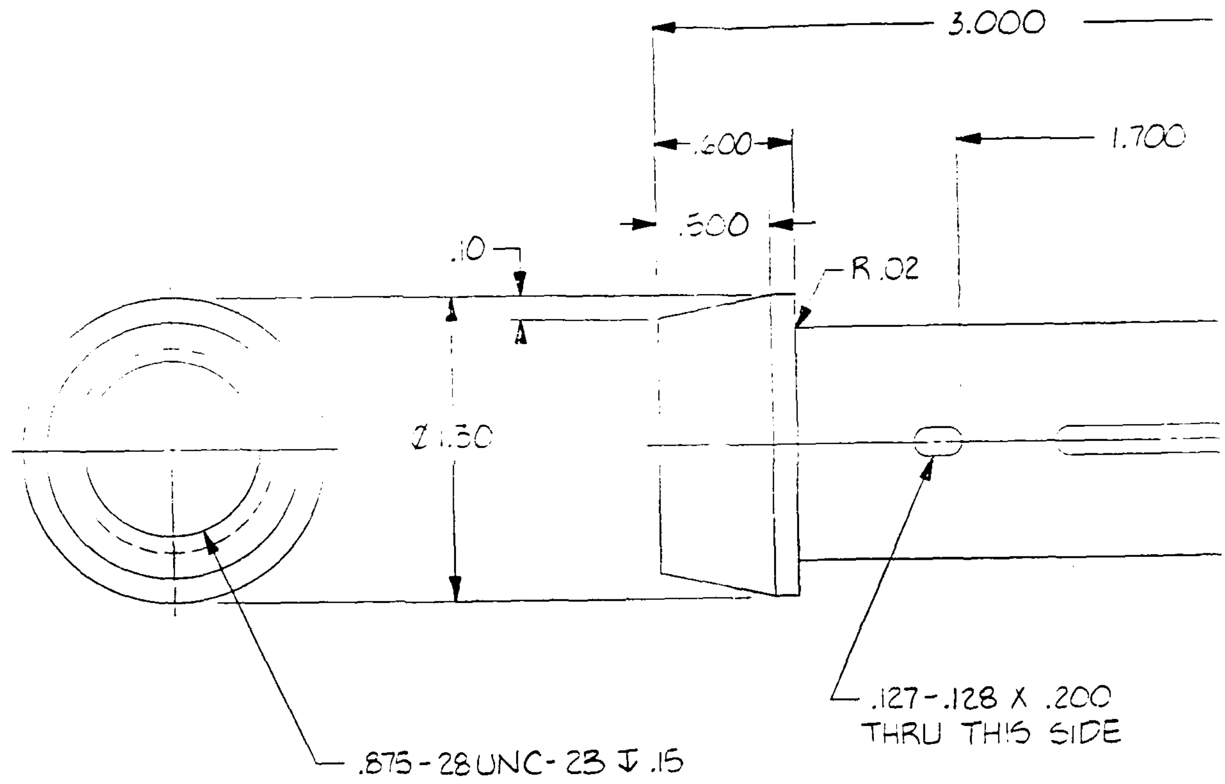
TITLE: PISTON

SIZE	FSCM NO.	DWG NO.	REV
B	13160	SK100470	—

SCALE 2/1 — SHEET 1 OF 1

NOTES:

1. MATERIAL: STEEL CRES TYPE 303 SE CR 303 SU CONDITION A.
2. REMOVE BURRS AND BREAK SHARP EDGES.



DSO 211-1 (rev 10-83)

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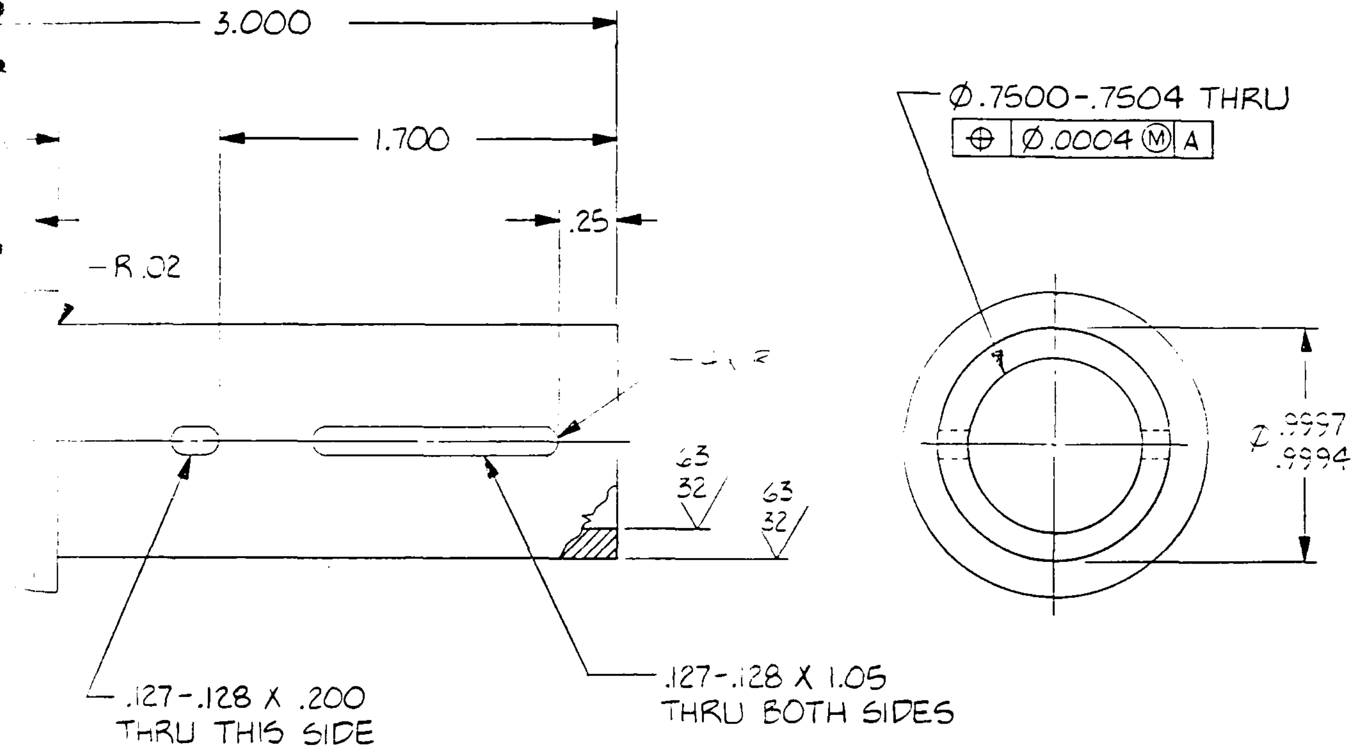
C

REVISIONS				
REV	DESCRIPTION	AUTH.	DATE	APPROVED



SIZE C | DWG NO 5K100468 | SH 1

REFERENCE ONLY

THE PART NUMBER IS THE DRAWING NUMBER AND THE DASH NUMBER THAT APPLIES

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES	CONTR. NO —		Delco Systems Operations
TOLERANCES ON 2 PLACE DECIMALS ±.01; 3 PLACE DECIMALS ±.005; ANGLES ± —	DFT S. Allen	87-4-28	GENERAL MOTORS CORPORATION GOLETA CALIFORNIA
	CHKR		TITLE SLIDER
MATERIAL SEE NOTE 1	ENGR	87-4-29	
	APVD	APVD	
	APVD	APVD	
	DSGN ACTIVITY APVD		SIZE C; FSCM NO. 13160; DWG NO. 5K100468; REV —
INTERPRET DRAWING PER DOD-STD-100	DO NOT SCALE DWG; REF E41		SCALE 2/1; SHEET 1 OF 1

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